Futuro quantistico, tecnologia e società

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Seeds from Ceeds, 4 maggio 2022

Università degli Studi di Milano, INFN Milano, CERN

In the news

Hillary Clinton wants “Manhattan-like project” to break encryption

US should be able to bypass encryption—but only for terrorists, candidate says.

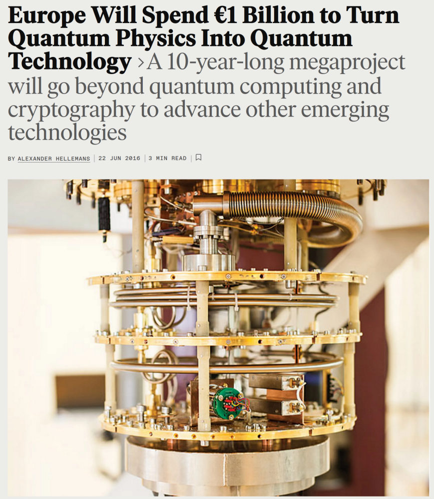
JON BRODKIN - 12/21/2015, 5:15 PM

Enlarge / Hillary Clinton's campaign acknowledged systems used by the campaign, hosted at the DNC, had been hacked, allegedly by a group tied to Russian intelligence agencies.

Presidential candidate Hillary Clinton has called for a "Manhattan-like project" to help law enforcement break into encrypted communications. This is in reference to the Manhattan Project, the top-secret concentrated research effort which resulted in the US developing nuclear weapons during World War II.

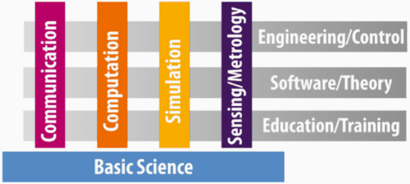
At Saturday's Democratic debate (transcript here), moderator Martha Raddatz asked Clinton about Apple CEO Tim Cook's statements that any effort to break encryption would harm law-abiding citizens.

Europe



Europe Will Spend €1 Billion to Turn Quantum Physics Into Quantum Technology › A 10-year-long megaproject will go beyond quantum computing and cryptography to advance other emerging technologies

BY ALEXANDER HELLEMANS | 22 JUN 2016 | 3 MIN READ



China will open a $10 billion quantum computer center and others also investing in quantum computing

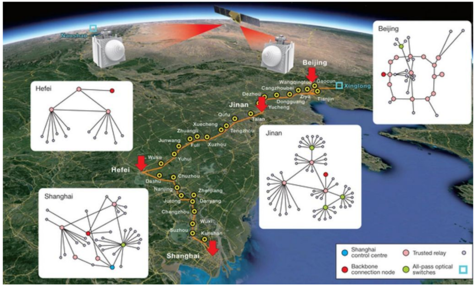
October 10, 2017 by Brian Wang

On 37 hectares (nearly 4 million square feet) in Hefei, Anhui Province, China is building a $10 billion research center for quantum applications. This news comes on the heels of the world's first video call made via quantum-encrypted communications and the completion of a quantum-encrypted fiber optic trunk cable.

China Builds the World's First Integrated Quantum Communication Network

TOPICS: Popular Quantum Information Science Telecommunications University Of Science And Technology Of China

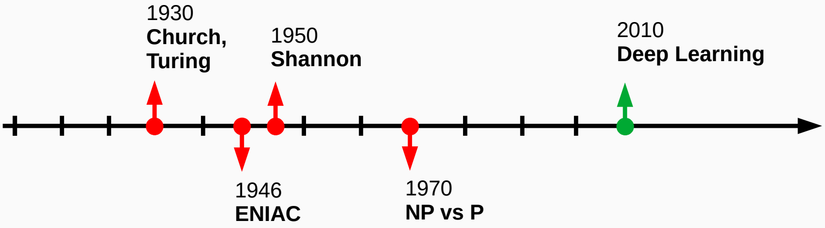
By UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA JANUARY 6, 2021



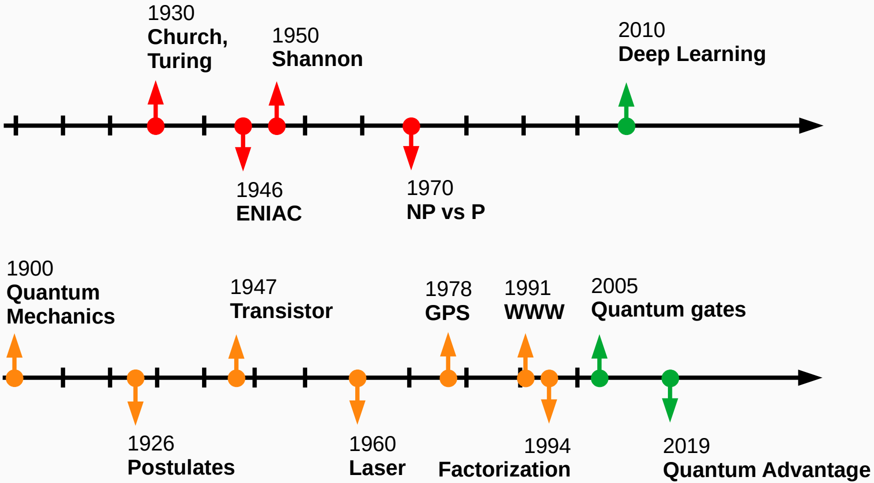
Chinese scientists have established the world's first integrated quantum communication network, combining over 700 optical fibers on the ground with two ground-to-satellite links to achieve quantum key distribution over a total distance of 4,600 kilometers for users across the country. Credit: University of Science and Technology of China

What's going on?

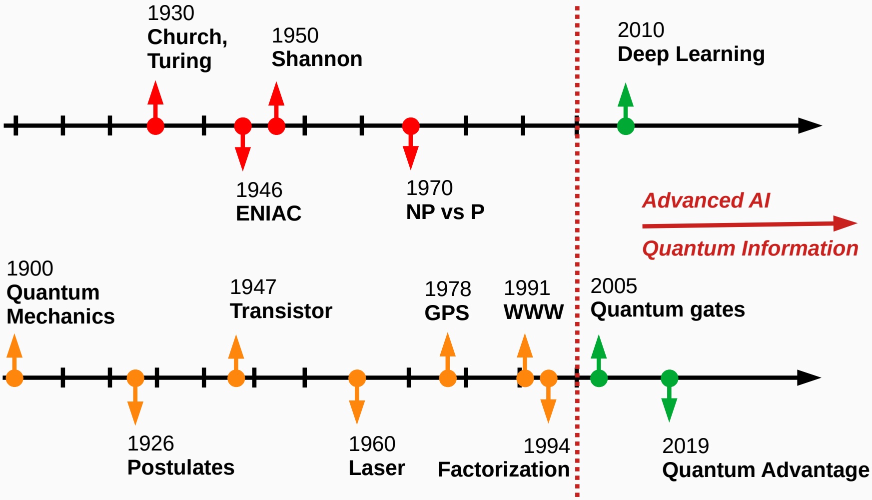
The Quantum Disruption



The Quantum Disruption



The Quantum Disruption



Acquiring control of nature at quantum level

First Quantum Revolution

Postulates and first applications:

- Transistors, computers
- Laser, communication
- Atomic clocks, GPS
- MRI, healthcare

Acquiring control of nature at quantum level

First Quantum Revolution

Postulates and first applications:

- Transistors, computers
- Laser, communication
- Atomic clocks, GPS
- MRI, healthcare

Second Quantum Revolution

Quantum control of quantum elements

- Quantum computation
- Quantum communication
- Quantum sensing
- Quantum simulation

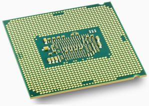
Acquiring control of nature at quantum level

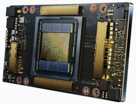
Towards **Quantum Information** and Computing

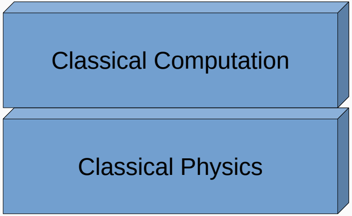
$\Downarrow$

Manipulate **information** with quantum mechanics

Information and Quantum Mechanics

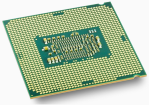


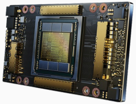


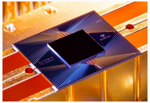


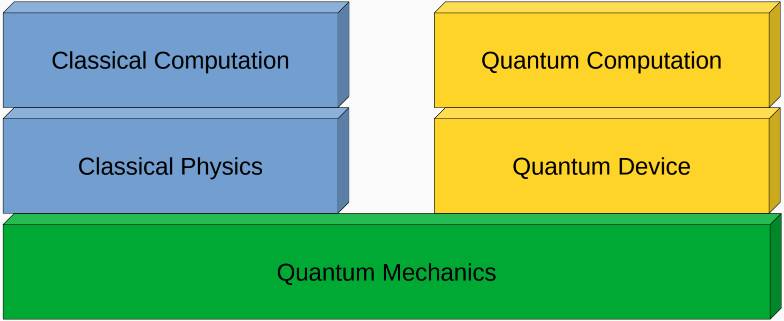
Computing = Physics: Church, Turing, ...

Information and Quantum Mechanics



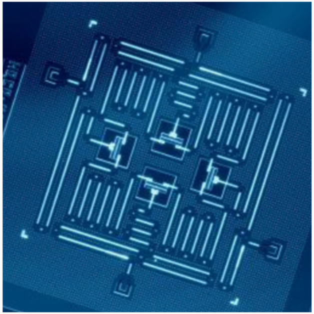




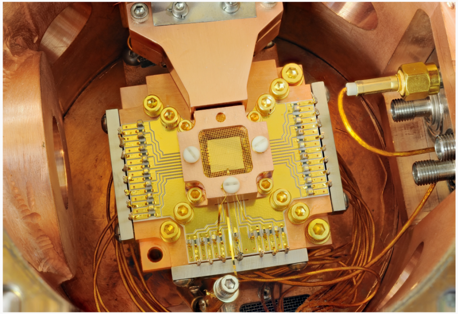


Feynman: Computing with Quantum Mechanics

Physical implementation



(a) Superconducting device assembled by IBM

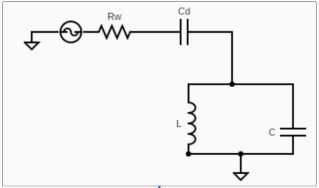


(b) Chip based on trapped ions techology

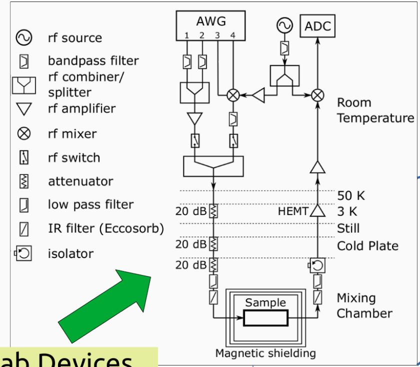
Physical implementation

Physical implementation

Transmon (qubit)



Platform design



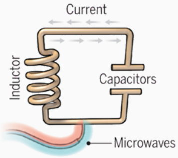
Lab Devices

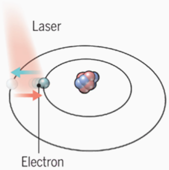
Cryostat (Fridge)

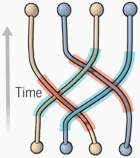
QRC@TII Labs

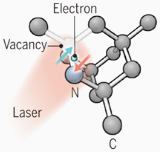
The big players

Quantum Technologies





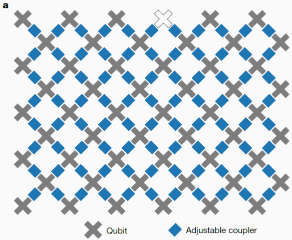


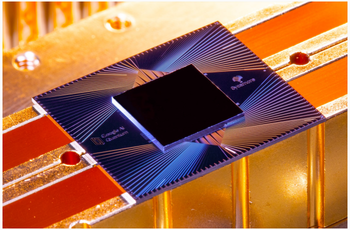


	Superconducting loops	Trapped ions	Silicon quantum dots	Topological qubits	Diamond vacancies
	A resistance-free current oscillates back and forth around a circuit loop. An injected microwave signal excites the current into super-position states.	Electrically charged atoms, or ions, have quantum energies that depend on the location of electrons. Tuned lasers cool and trap the ions, and put them in superposition states.	These "artificial atoms" are made by adding an electron to a small piece of pure silicon. Microwaves control the electron's quantum state.	Quasiparticles can be seen in the behavior of electrons channeled through semi-conductor structures. Their braided paths can encode quantum information.	A nitrogen atom and a vacancy add an electron to a diamond lattice. Its quantum spin state, along with those of nearby carbon nuclei, can be controlled with light.
Number entangled	9	14	2	N/A	6
Company support	Google, IBM, Quantum Circuits	ionQ	Intel	Microsoft, Bell Labs	Quantum Diamond Technologies
Pros	Fast working. Build on existing semiconductor industry.	Very stable. Highest achieved gate fidelities.	Stable. Build on existing semiconductor industry.	Greatly reduce errors.	Can operate at room temperature.
Cons	Collapse easily and must be kept cold.	Slow operation. Many lasers are needed.	Only a few entangled. Must be kept cold.	Existence not yet confirmed.	Difficult to entangle.

Quantum advantage

First quantum computation that can not be reproduced on a classical supercomputer from Google, Nature 574, 505-510(2019):

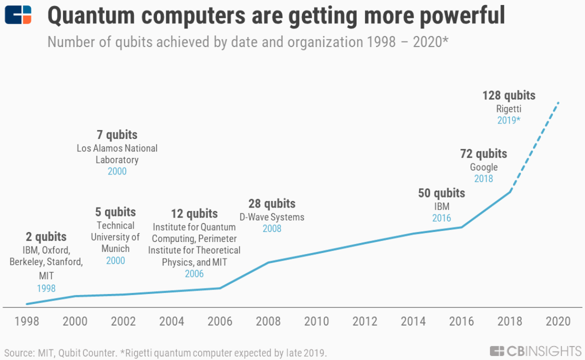


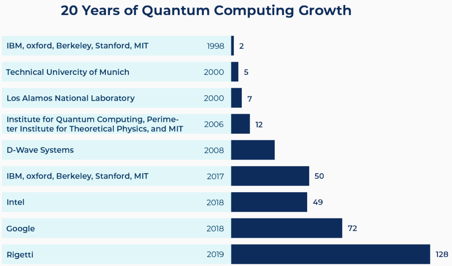


53 qubits (86 qubit-couplers) $\rightarrow$ Task of sampling the output of a pseudo-random quantum circuit (extract probability distribution).

Classically the probability distribution is exponentially more difficult.

Qubit counter





The big players

Full-Stack (End-to-End)
- Google
- IBM
- Microsoft
- amazon
- Honeywell
- rigetti
- Alibaba Group 阿里巴巴集团
- D-Wave The Quantum Computing Company
- XANADU

Software Applications
- RIVERLANE
- Menten AI
- ZAPATA
- QCWARE
- MULTIVERSE COMPUTING
- JoS QUANTUM
- QBITLOGIC
- QRITHM
- QULAB

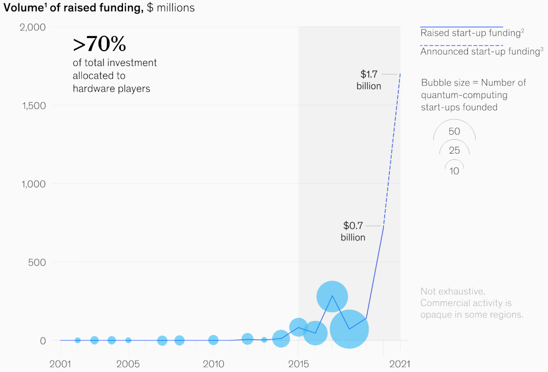
Cloud Computing
- agnostiq
- QCWARE
- 1QBit
- BraneCell
- Aliro QUANTUM
- BLACK BRANE

Quantum Encryption and AI
- ISARA
- agnostiq
- Post-Quantum
- SPEQTRAL
- PQSHIELD
- IDQ
- ZY4

Systems & Firmware
- 1QBit
- Q-CTRL
- QINDOM
- Aliro QUANTUM
- STRANGE WORKS
- quantum benchmark
- CQC CAMBRIDGE QUANTUM COMPUTING
- Labber QUANTUM
- QUANTUM MACHINES
- QILIMANJARO

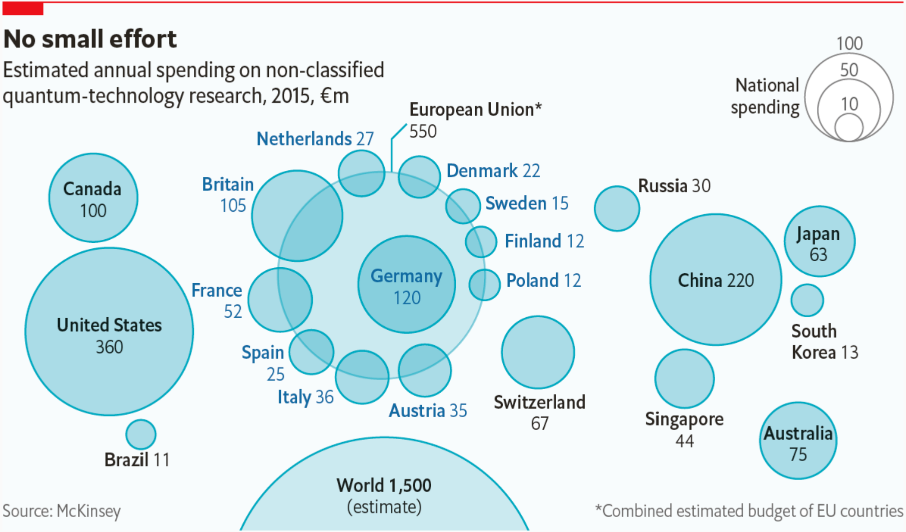
Quantum Hardware
- ColdQuanta
- qci Quantum Circuits, Inc
- IONQ
- PsiQ
- EeroQ
- IQM
- QUANTUM FACTORY
- QUANDELA
- Delft Circuits
- Quantum Microwave

Start-up activity and investments in quantum computing have skyrocketed since 2015.

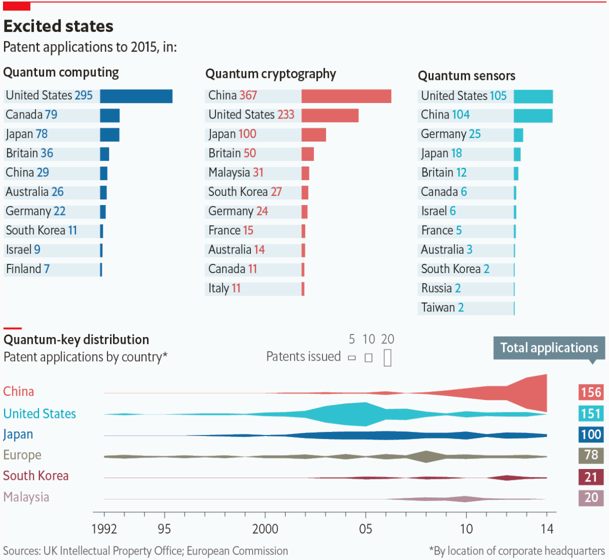


[1]Based on public investment data recorded in PitchBook; actual investment is likely higher.
[2]Public announcements of major deals; actual investment is likely higher.
[3]Start-ups from 2019 and later are likely still in stealth mode or are not yet recognized as quantum-computing companies by relevant platforms and experts.
Source: PitchBook; McKinsey analysis

Annual spending on quantum technology

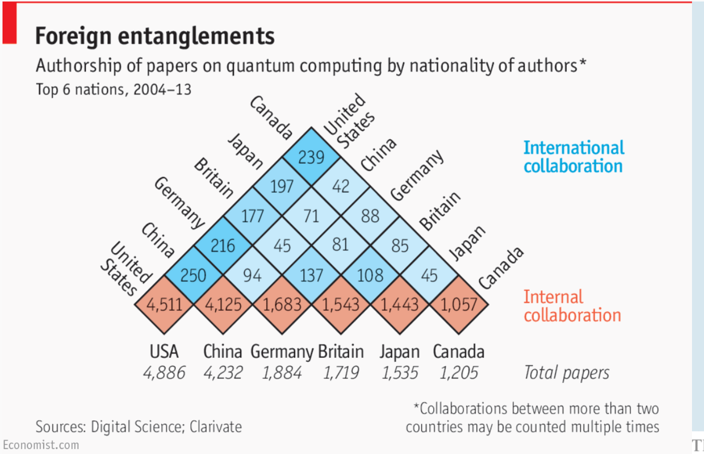


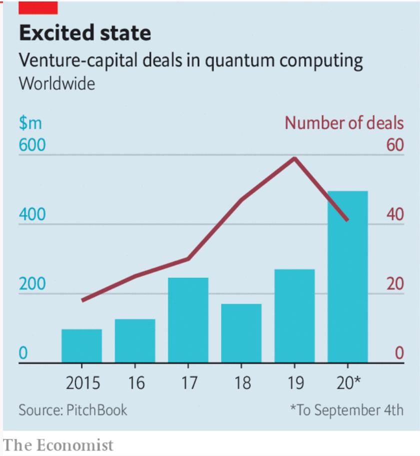
Patents



Excited states
Patent applications to 2015, in:
Quantum computing
United States 295
Canada 79
Japan 78
Britain 36
China 29
Australia 26
Germany 22
South Korea 11
Israel 9
Finland 7
Quantum cryptography
China 367
United States 233
Japan 100
Britain 50
Malaysia 31
South Korea 27
Germany 24
France 15
Australia 14
Canada 11
Italy 11
Quantum sensors
United States 105
China 104
Germany 25
Japan 18
Britain 12
Canada 6
Israel 6
France 5
Australia 3
South Korea 2
Russia 2
Taiwan 2
Quantum-key distribution
Patent applications by country*
Patents issued
5 10 20
Total applications
China 156
United States 151
Japan 100
Europe 78
South Korea 21
Malaysia 20
1992 95 2000 05 10 14
Sources: UK Intellectual Property Office; European Commission
*By location of corporate headquarters

The big players





Summary

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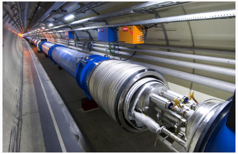
Quantum technology is not a fashion or a simple hype!

Funding and interest is large and in continuous growing.



LHC at CERN: 4.5B Euros

Summary

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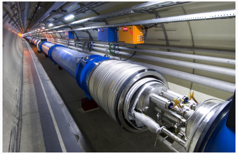
Funding and interest is large and in continuous growing.



LHC at CERN: 4.5B Euros

Open questions:

- Which development model is the most **sustainable** for future technological research?
- How to measure its **cost-benefit**?
- What's the **impact** in our society?