Think Tank

- Intellectual exchange
- Own publishing house

Business Network

- Ambassador level
- International contacts

Charitable Foundation

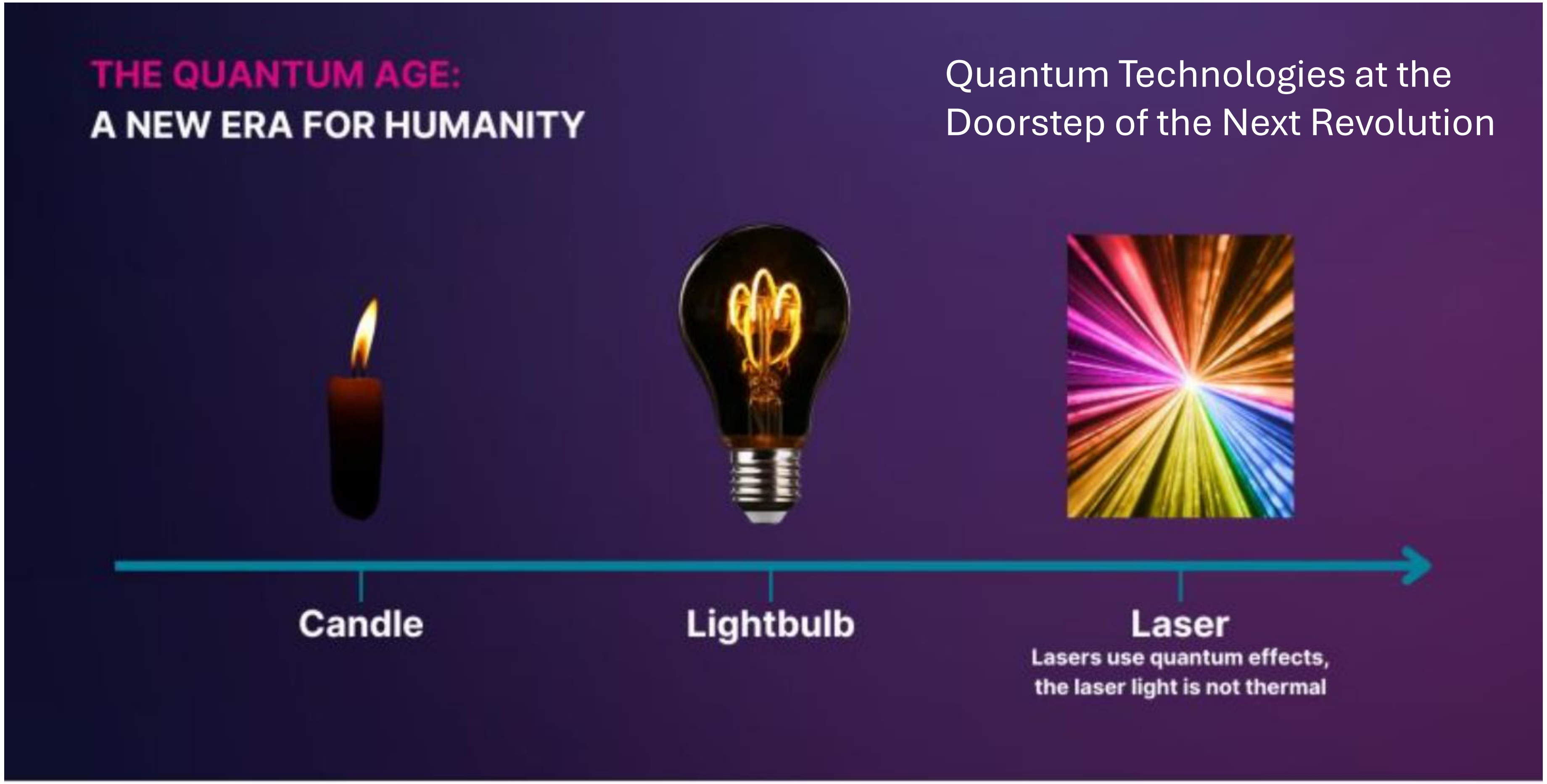
28th CSTD side event:

Presentation of

“The Quantum Technology for the Development of Humanity”

Diplomatic Council Quantum Leap Initiative

UN Speech – Committee for Science and Technology



eleQtron

“ **The concept of a quantum computer was first proposed by the theoretical physicist and Nobel laureate Richard Feynman in 1981.**

Feynman came of age during the dawn of quantum mechanics, when scientists began to recognize that atoms, electrons, light, and other sub-nanoscale objects - building blocks for everything in the universe - obey fundamentally different rules than the objects of everyday life.

Unlike, for example, **a ball**, which follows the straightforward rules of classical mechanics, electrons behave simultaneously as particles and waves, and their location cannot be exactly defined. ”

from THE FOREIGN AFFAIRS:

The Race to Lead the Quantum Future

How the Next Computing Revolution Will Transform the Global Economy and Upend National Security

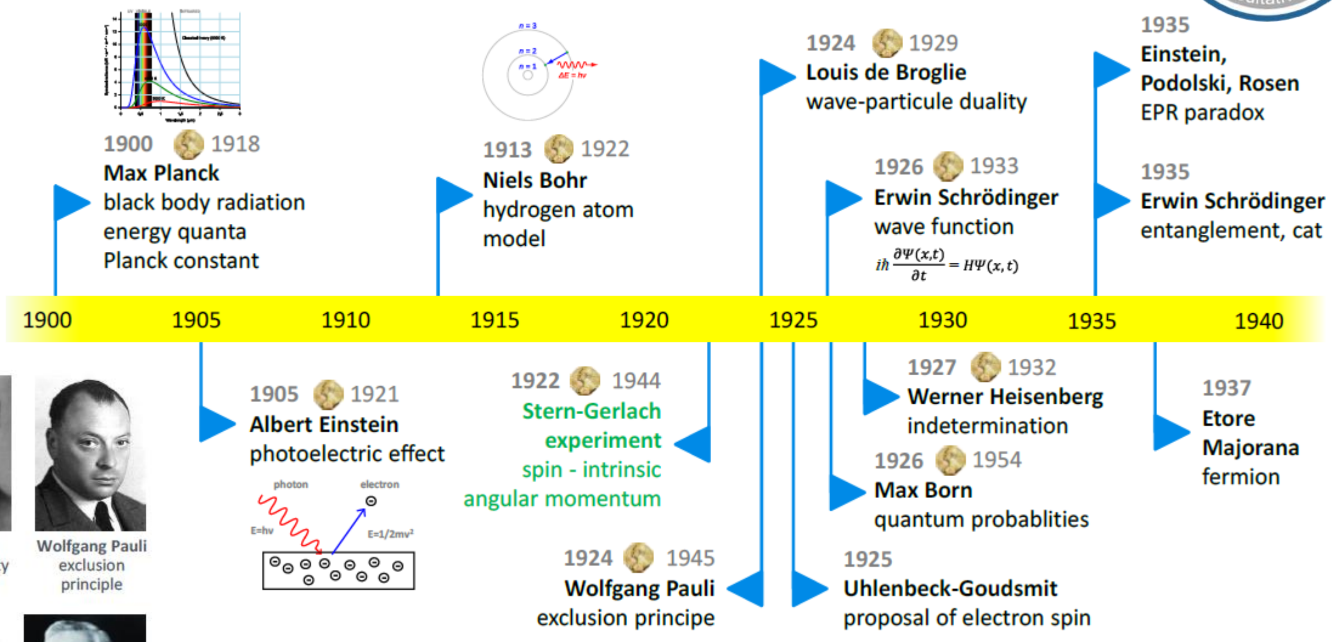
Charina Chou, James Manyika, and Hartmut Neven

January/February 2025, © *Published on January 7, 2025*

100 Years Quantum Mechanics

The quantum technology revolution started already 100 years ago

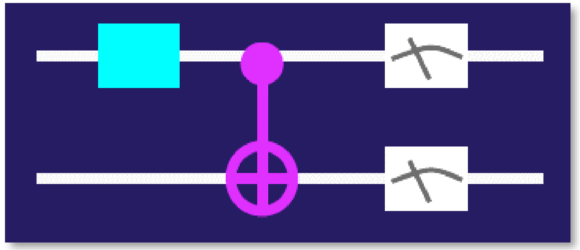
The key founders of quantum physics in the first part of the 20th century.



Quantum physics foundational years timeline. In green, experimentalist works, in black, theoretician works. The gold coins represent a Nobel prize.

100 Years Quantum Mechanics

The 2nd quantum technology revolution thrived within the last decades since the 1970's – 1980's



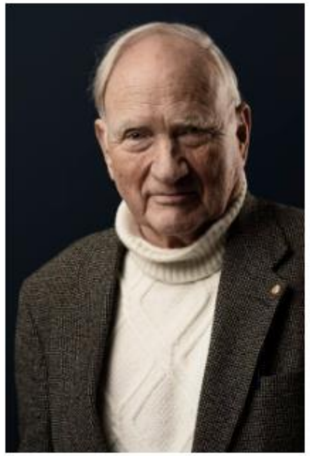
Nobel Prize in Physics 2022

- Summary
- Laureates
  - Alain Aspect
  - John Clauser
  - Anton Zeilinger
- Prize announcement
- Press release
- Popular information
- Advanced information
- Award ceremony video
- Award ceremony speech

Share this

Nobel Prize in Physics 2022

© Nobel Prize Outreach. Photo: Stefan Bladh
Alain Aspect
Prize share: 1/3



© Nobel Prize Outreach. Photo: Stefan Bladh
John F. Clauser
Prize share: 1/3

© Nobel Prize Outreach. Photo: Stefan Bladh
Anton Zeilinger
Prize share: 1/3

The Nobel Prize in Physics 2022 was awarded jointly to Alain Aspect, John F. Clauser and Anton Zeilinger "for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science"

https://www.nobelprize.org/prizes/physics/2022/summary

100 Years Quantum Mechanics – research lingers on

The 3rd quantum revolution
is visible at the horizon
of scientific research

equation: ER = EPR

[which is derived from an transformation of the **E**instein-**P**odolsky-**R**osen Paradoxon whereas **ER** is **E**instein-**R**osen-bridge (wormhole)]

© Imaging ChatGPT 4o

100 Years Quantum Mechanics – research publishing

The 3rd quantum revolution


The Stretched Horizon and Black Hole Complementarity

Leonard Susskind,* Lárus Thorlacius,† and John Uglum‡

Department of Physics
Stanford University, Stanford, CA 94305-4060

arXiv:hep-th/9306069v2 28 Jun 1993

Black Holes: Complementarity or Firewalls?

Ahmed Almheiri,* Donald Marolf,*† Joseph Polchinski,† and Ja

Department of Physics
University of California
Santa Barbara, CA 93106

†*Kavli Institute for Theoretical Physics*
University of California
Santa Barbara, CA 93106-4030

We argue that the following thr
radiation is in a pure state, (ii) the
from the region near the horizon, wi
some microscopic distance from the h
nothing unusual at the horizon. P
the infalling observer burns up at t
novel dynamics that nevertheless ca
macroscopic distances from the horiz

Xiv:1207.3123v4 [hep-th] 13 Apr 2013

Cool horizons for entangled black holes

Juan Maldacena[1] and Leonard Susskind[2]

[1] Institute for Advanced Study, Princeton, NJ 08540, USA

[2] Stanford Institute for Theoretical Physics and Department of Physics, Stanford University, Stanford, CA 94305-4060, USA

Abstract

General relativity contains solutions in which two distant black holes are con-

v:1306.0533v2 [hep-th] 11 Jul 2013

Black holes as mirrors: quantum information in random subsystems

Patrick Hayden
School of Computer Science, McGill University, Montreal, Quebec, H3A 2A7, Canada

John Preskill
Institute for Quantum Information, California Institute of Technology, Pasadena CA 91125, USA

Abstract

We study information retrieval from evaporating black holes, assuming that the internal dynamics of a black hole is unitary and rapidly mixing, and assuming that the retriever has unlimited control over the emitted Hawking radiation. If the evaporation of the black hole has already proceeded past the "half-way" point, where half of the initial entropy has been radiated away, then additional quantum information deposited in the black hole is revealed in the Hawking radiation very rapidly. Information deposited prior to the half-way point remains concealed until the half-way point, and then emerges quickly. These conclusions hold because typical local quantum circuits are efficient encoders for quantum error-correcting codes that nearly achieve the capacity of the quantum erasure channel. Our estimate of a black hole's information retention time, based on speculative dynamical assumptions, is just barely compatible with the black hole complementarity hypothesis.

1 Introduction

8.4025v2 [hep-th] 21 Sep 2007

Currently Theoretical Physicists working in Quantum Gravity struggling in solving the most challenging problem:

<u>The Black Hole Information Paradoxon</u>

- The breathtaking 2013‘ paper by „AMPS“presents a possible solution to an apparent inconsistency in black hole complementarity.
- Black hole complementarity is a conjectured solution to the black hole information paradox: proposed by L. Susskind, L. Thorlacius, J. Uglum, and G.'t Hooft in 1993
- The AMPS proposal and discussions in the Physics Community led J. Maldacena and L. Susskind to ER=EPR proposal -> Outgoing and infalling particles in Black Holes are somehow connected by wormholes!

100 Years Quantum Mechanics – UNESCO

Sir Peter Knight:

„We need all of you to change the world“

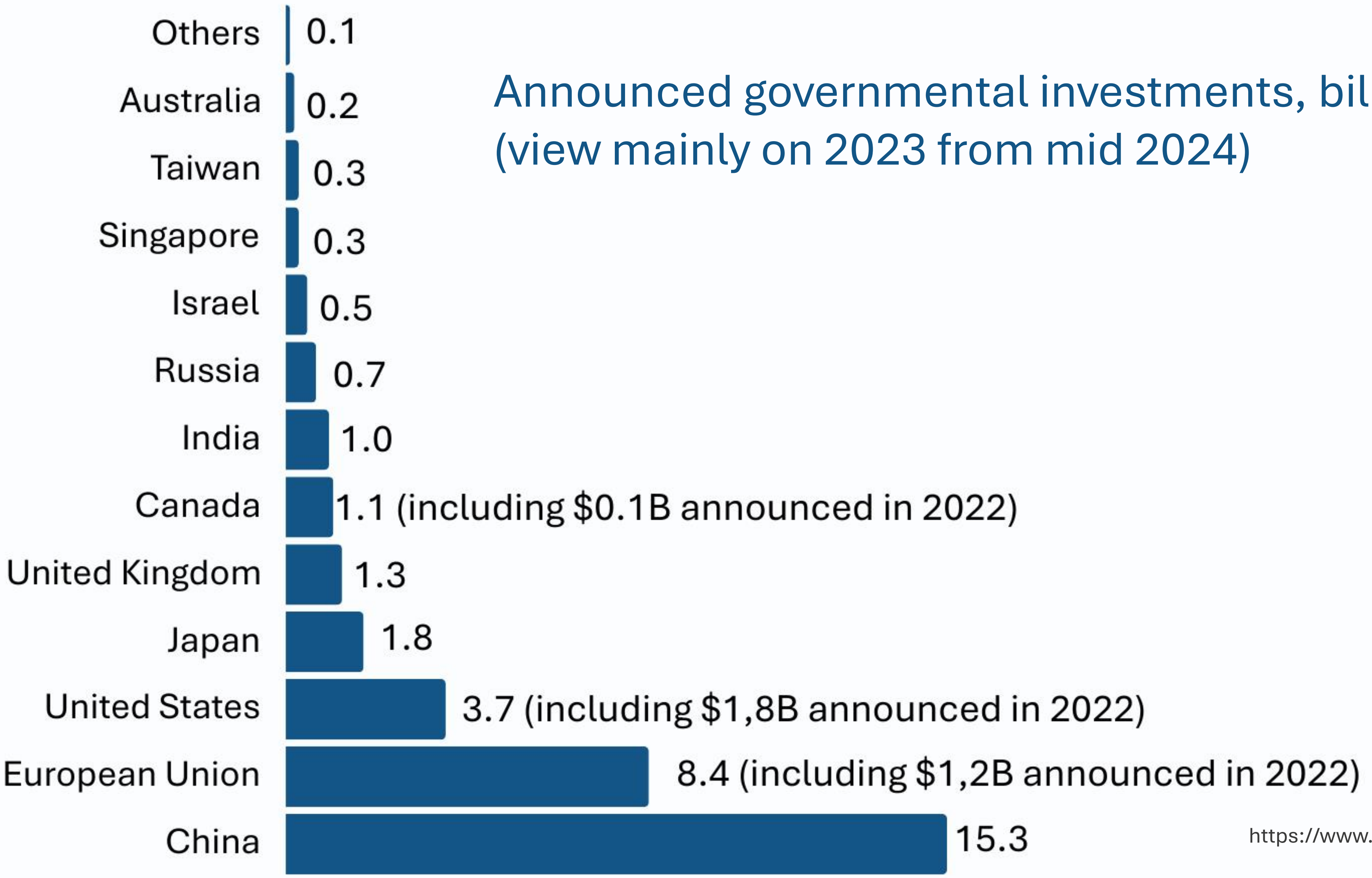
The 2025 International Year of Quantum Science and Technology (IYQ) recognizes 100 years since the initial development of quantum mechanics. Join us at the Opening Ceremony taking place at the UNESCO Headquarters in Paris, France, from February 4-5, to celebrate the Launch of IYQ 2025!

Details:
4 February 2025 – 9:00 am – 5 February 2025 – 1:00 pm
UNESCO Headquarters, Paris, France
Room I & Room II

https://www.unesco.org/

Global Quantum Technologies Governmental Budgets for Research

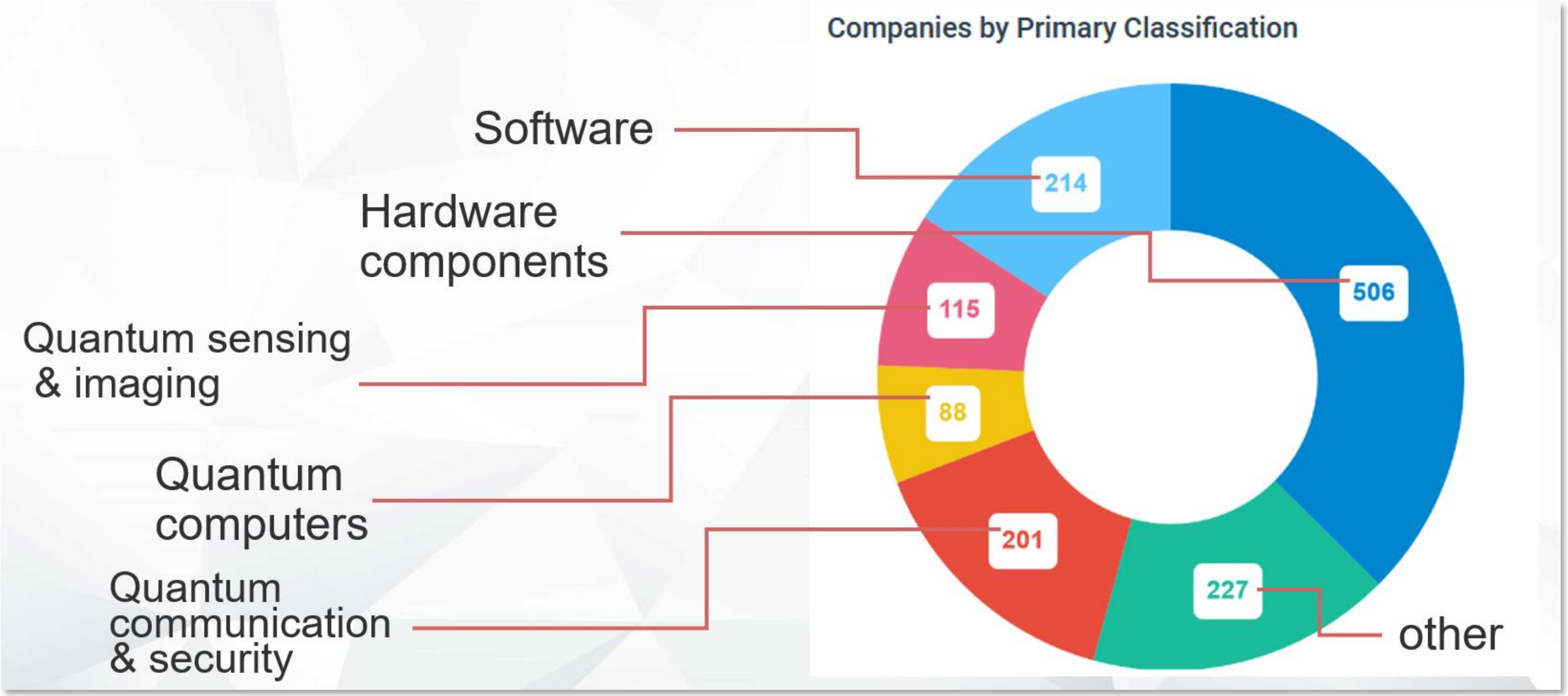
Announced governmental investments, billion$
(view mainly on 2023 from mid 2024)



https://www.mckinsey.com/

Global Quantum Technologies Venture Capital at Work

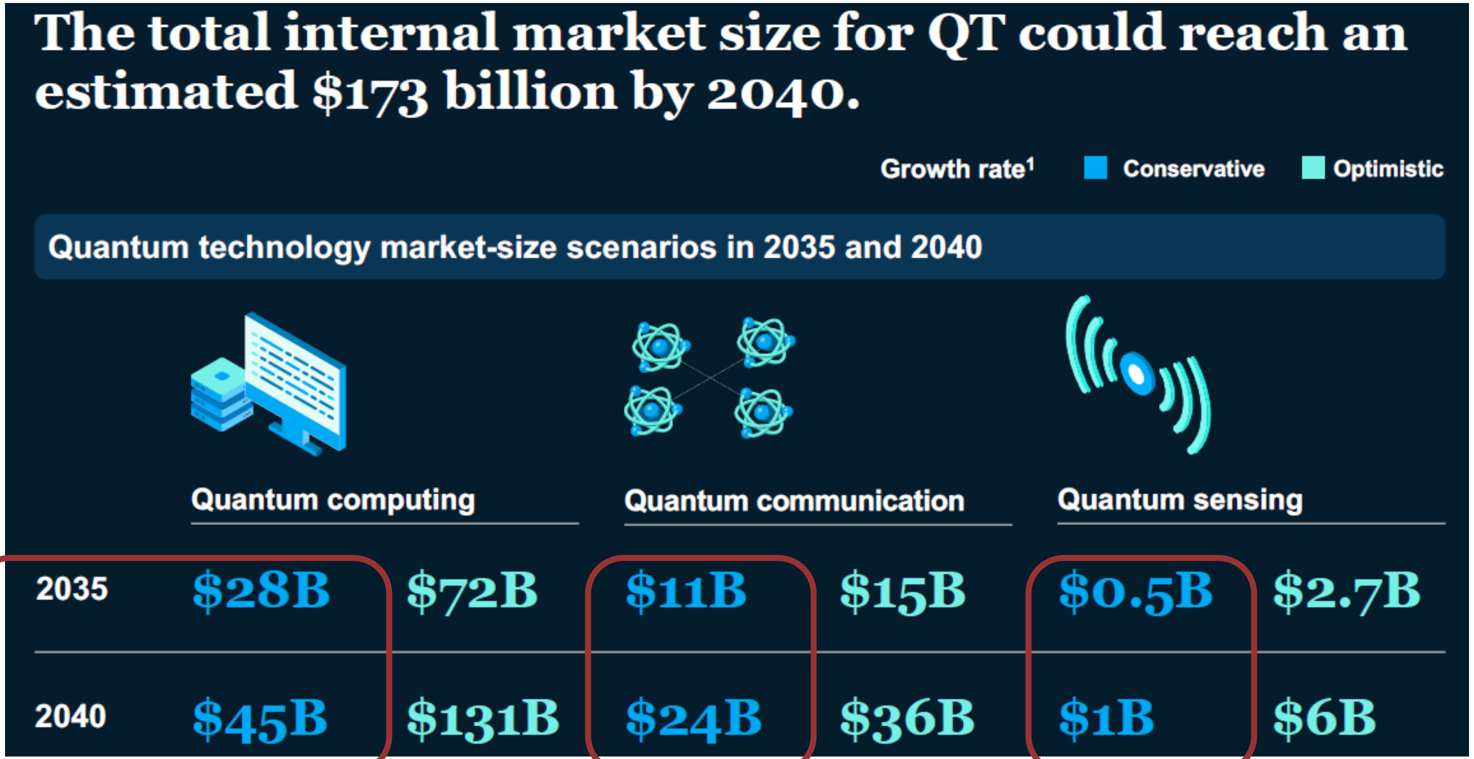
New business ingniting promising StartUp investments



https://app.thequantuminsider.com/

Global Quantum Technologies Market Estimates

Even conservative figures show immense potential of QT!



The total internal market size for QT could reach an estimated $173 billion by 2040.

Growth rate[1] ■ Conservative ■ Optimistic

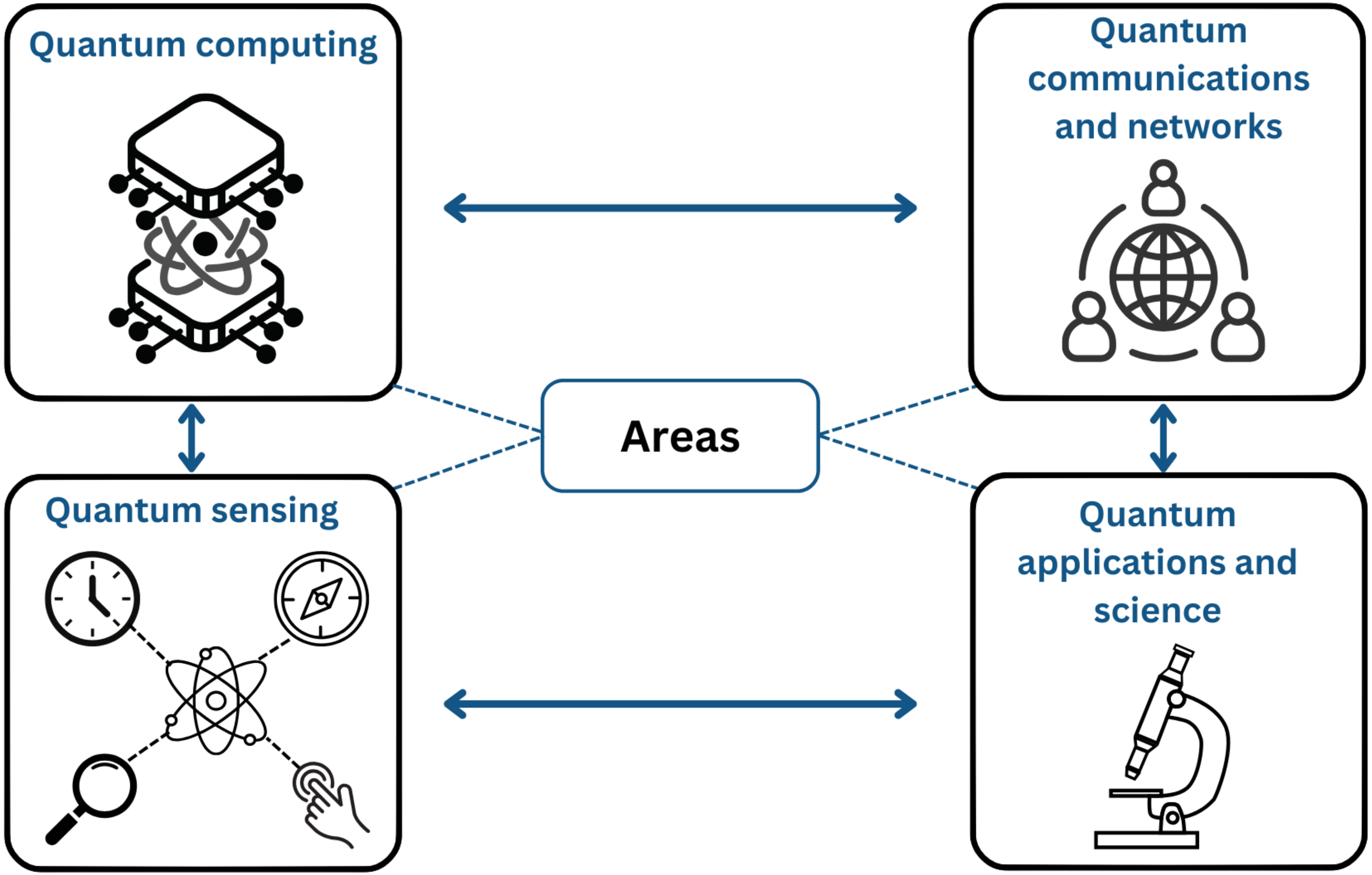
Quantum technology market-size scenarios in 2035 and 2040

	Quantum computing		Quantum communication		Quantum sensing	
2035	$28B	$72B	$11B	$15B	$0.5B	$2.7B
2040	$45B	$131B	$24B	$36B	$1B	$6B

https://www.mckinsey.com/

Global Research Race for Quantum Findings

What Quantum Technology means, how it works and why it is a 'Quantum Leap'



Caveats – Mindsetting for Quantum Technology Items

Most popular quantum misunderstandings

🌀 Quantum = Magic or Sci-Fi:
Quantum mechanics is often exaggerated in media and pop culture as mystical or supernatural.

🧠 Quantum Computers Think Like Humans:
They process information fundamentally differently from the human brain or classical AI systems.

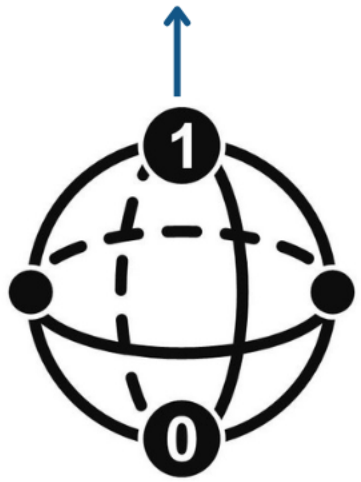
🧪 Quantum Mechanics Is Only Theoretical:
In reality, quantum phenomena are tested and applied (e.g., in lasers, MRI, semiconductors).

🔐 Quantum Cryptography = Unhackable Security:
While extremely secure in theory, practical systems can still be vulnerable due to implementation flaws.

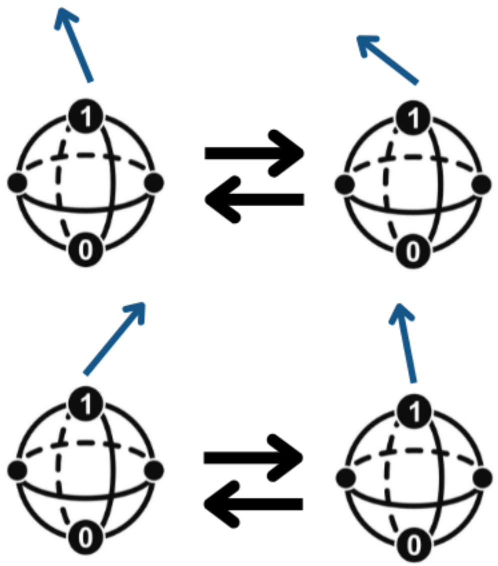
⚛️ Particles Can Be in Two Places at Once:
Misinterpretation of superposition—particles have a probability distribution, not dual existence.

🕳️ Quantum Tunneling Means Traveling Through Walls:
It refers to a probabilistic effect at microscopic scales, not macroscopic teleportation.

About Qbits and their States

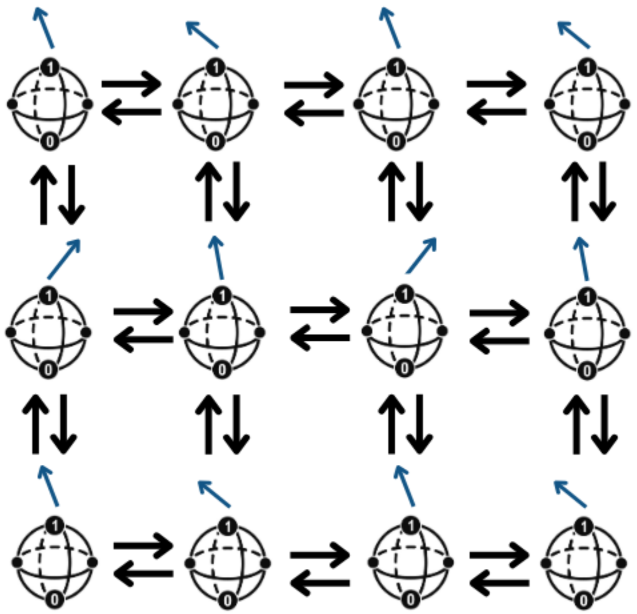


Generate and control individual qubits



+ Increase in the number of qubits
+ Increase in gate fidelity
+ Stable entanglement
+ First error corrections

– Short coherence times
– Lower gate fidelity



+ Very many qubits
+ Logical error-free qubits
+ Complete entanglement
+ Long coherence times
+ High gate fidelity
+ Fast switching times

Time

Beginnings and current basic research

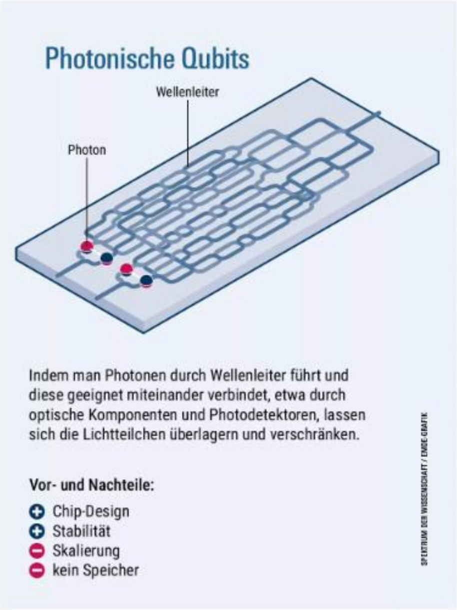
Today's quantum computers

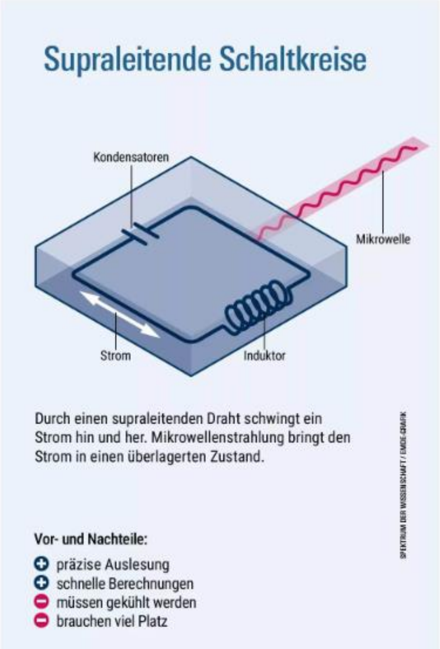
Vision of an “error-free” quantum computer

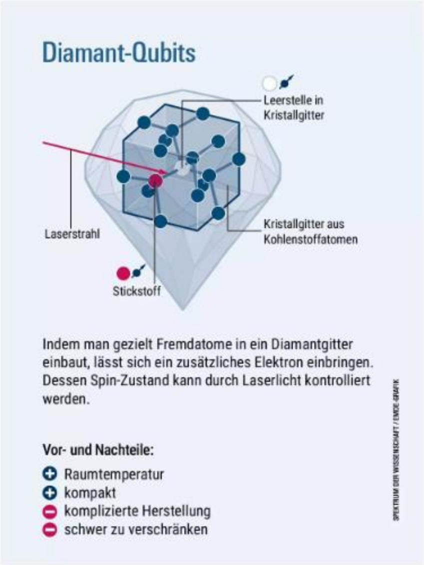
Quantum Computing Platforms competitive edge (German popular science magazine)

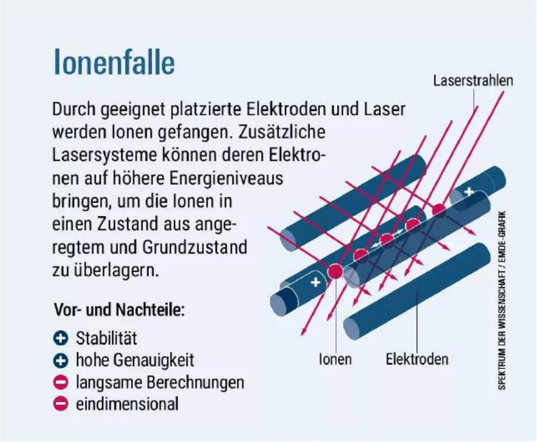
Evolving chip design: quantum computers still lack preciseness and stability related to weak error correction and engineering challenges

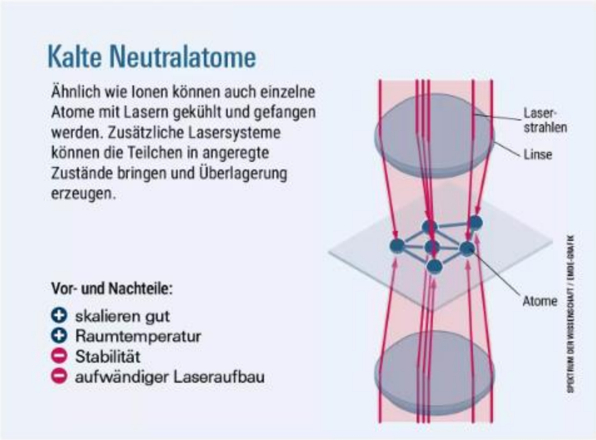
Quantum computing

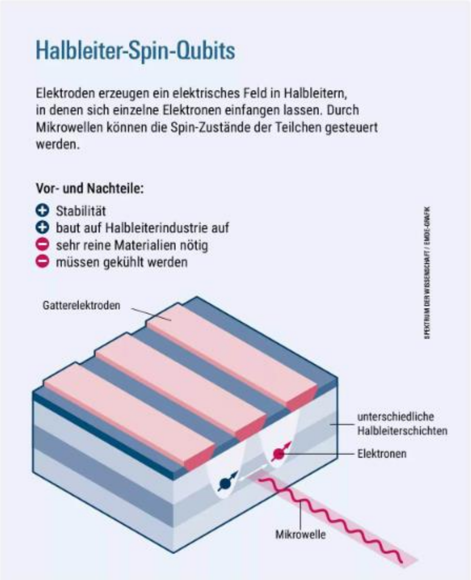








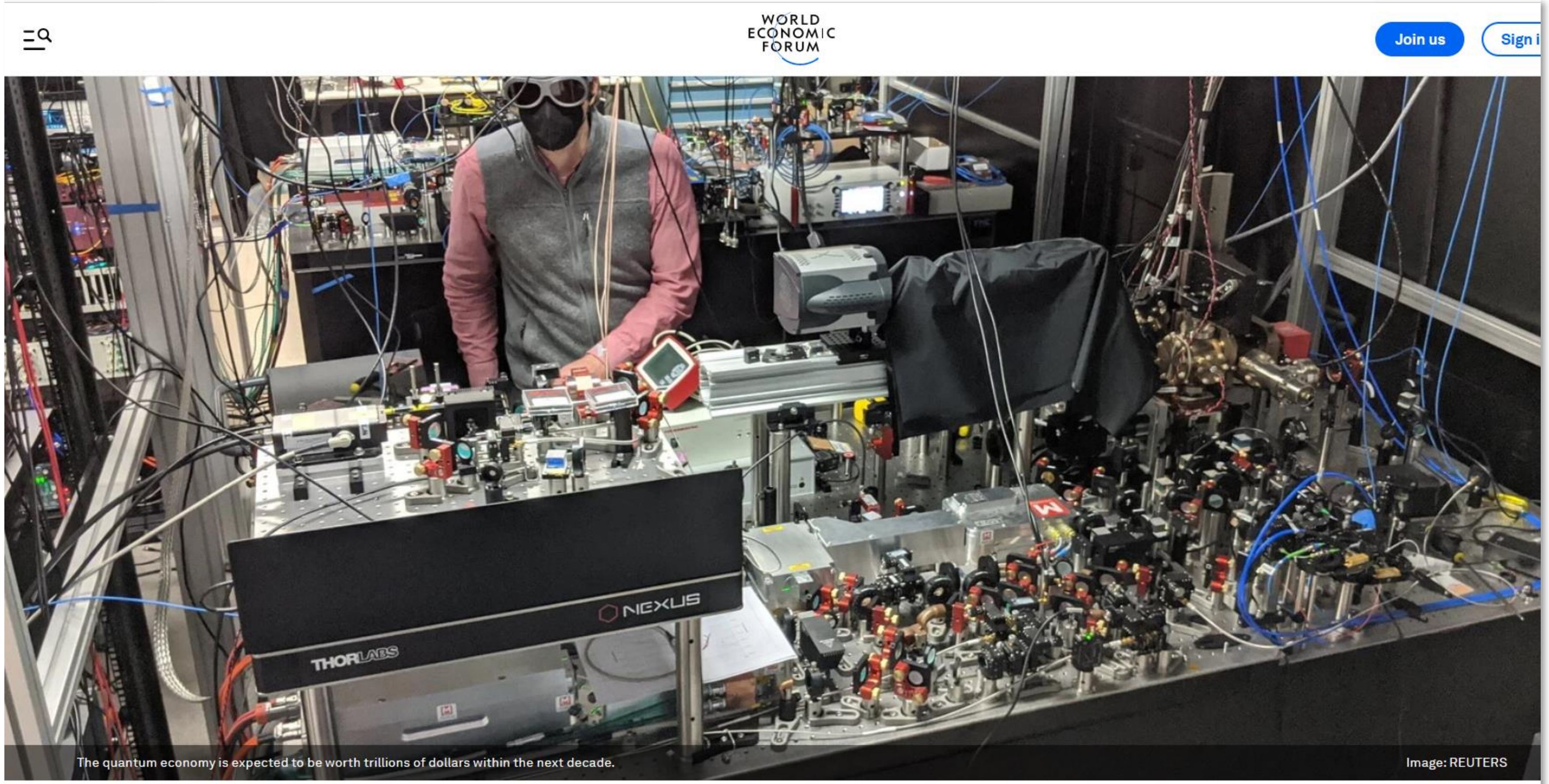




Quantum Computing Platforms driving the Quantum economy

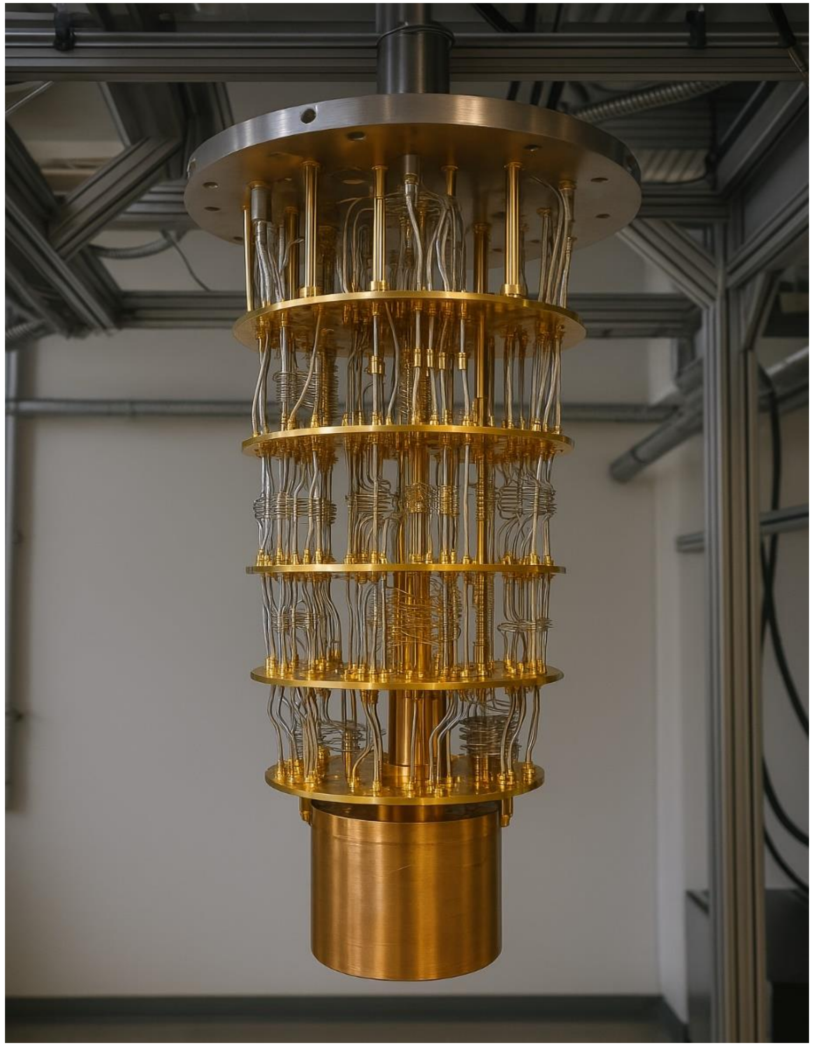
Quantum computing

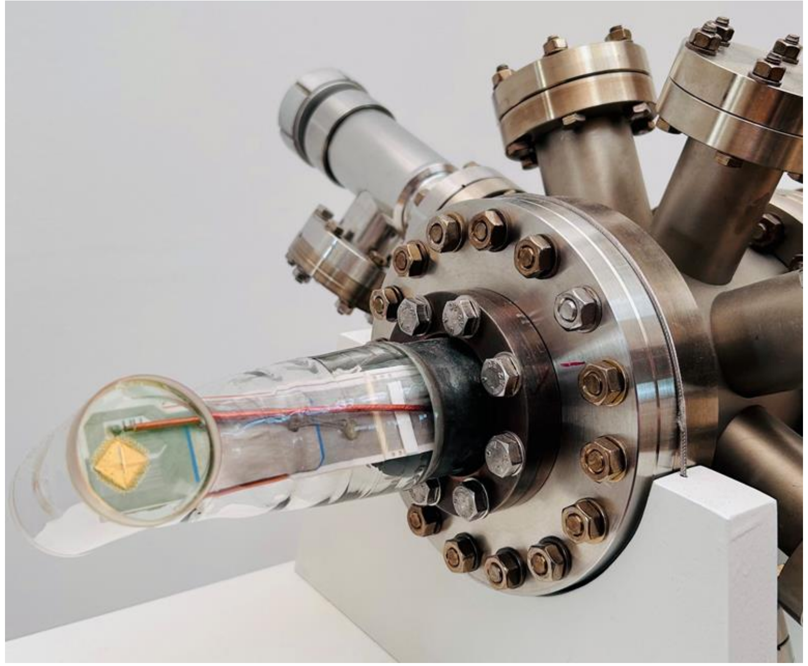
Engineering and research: One-by-one the progress spirales through distinct efforts to meet expectations and show the required stability which is essential.

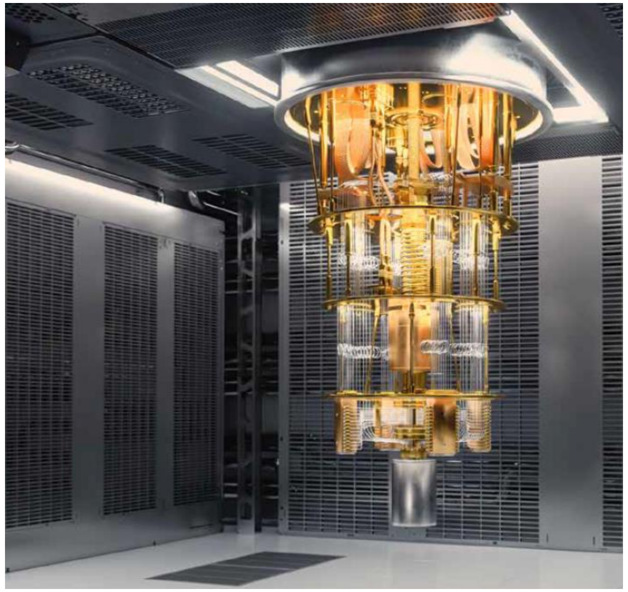


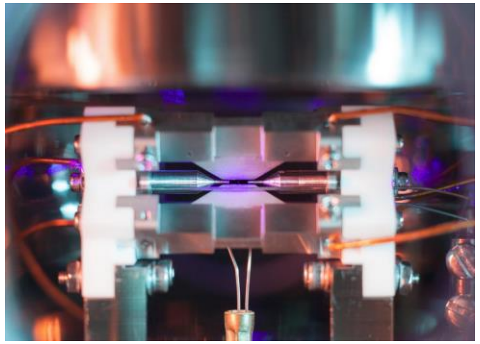
https://www.weforum.org

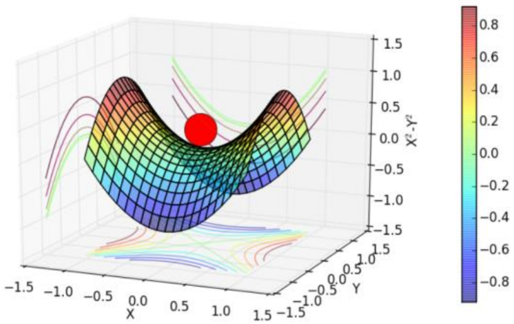
Quantum Computers look very much different, platform related











- SUPERCONDUCTING / ION-TRAP / NV-CENTER -

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ChatGPT 4o / Rosenberger HFT
https://www.physics.ox.ac.uk/research
parityqc.com

QT Communications and -Networks

A Network that connects quantum computers and devices via entanglement

Core technologies

- QKD
- Quantum entanglement-based communication
- Trusted node networks

Limitations

- Range
- Infrastructure
- Cost
- Speed

Quantum communications and networks

enables

- **Ultra-secure communication**
- Distributed quantum computing
- Quantum sensor networks

The future of quantum communication:

- Quantum repeaters
- Satellite-based quantum links
- Quantum Internet

Satellite-Based Quantum Communication

Enabling global QKD & quantum networks

Motivation

- Global connection possible
  - Loss does not scale with distance between users on earth
  - Sources on satellites, users receive signal on earth
  - QKD now, networks next step
- Status
  - First demonstration 2017 (China)
  - Several missions in preparation (China, ESA, EU, Canada)

Technology

- Space sources
  - Send quantum states from space entangled or prepare & measure
  - High rate & quality needed

- Optical qround stations
  - Telescope system
  - Quantum state detection

The Final Stage: Quantum Internet

A network that connects quantum computers and devices via entanglement

Enabling:

- Ultra-secure communication
- Distributed quantum computing
- Quantum sensor networks

Next steps: Device Miniaturization & Integration

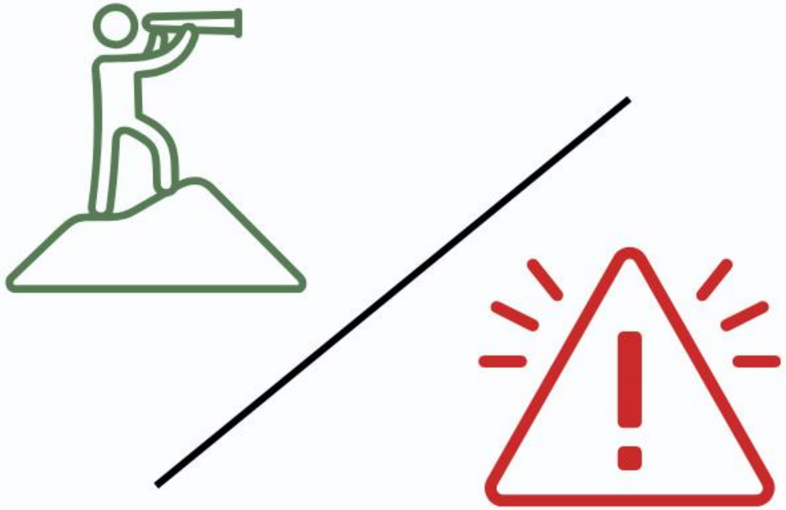
Long-Term Vision:

- **Unhackable communications** for governments, banks, defense, and critical infrastructure
- **Global quantum networks** linking quantum computers and sensors.
- **Hybrid classical-quantum networks** for secure internet layers

Opportunities and Threats of Quantum Technologies

How far until our Quantum technology future is achieved?

Solving unresolved problems

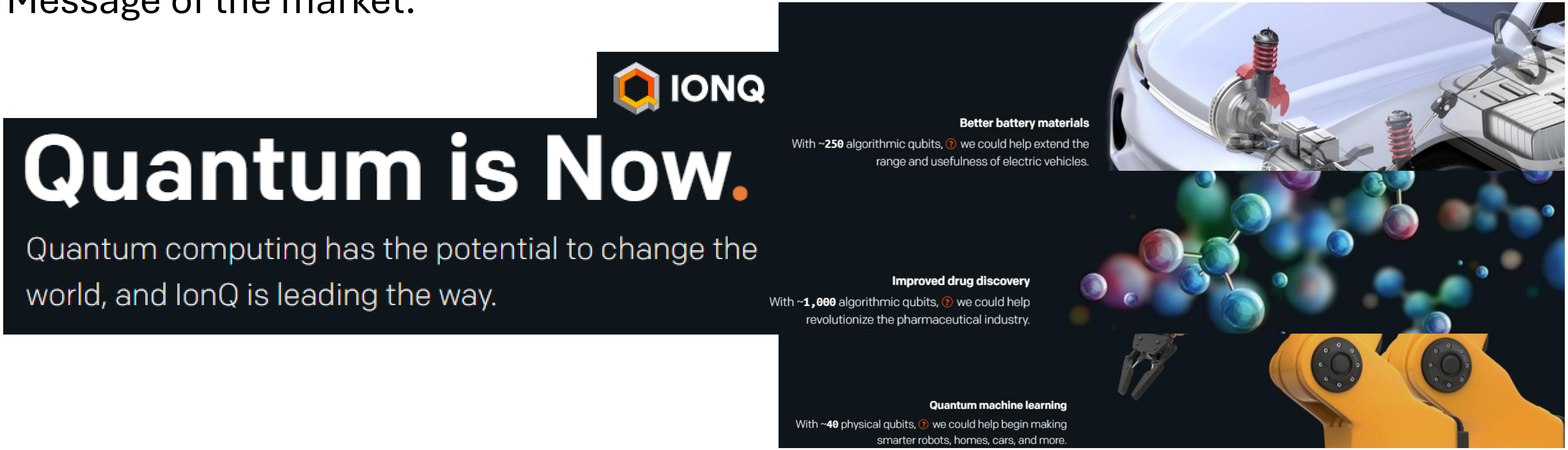


Creating wealth

Security and data protection

How far until our Quantum Technology Future is achieved?

Message of the market:



<u>Confusing messages</u> of the market:

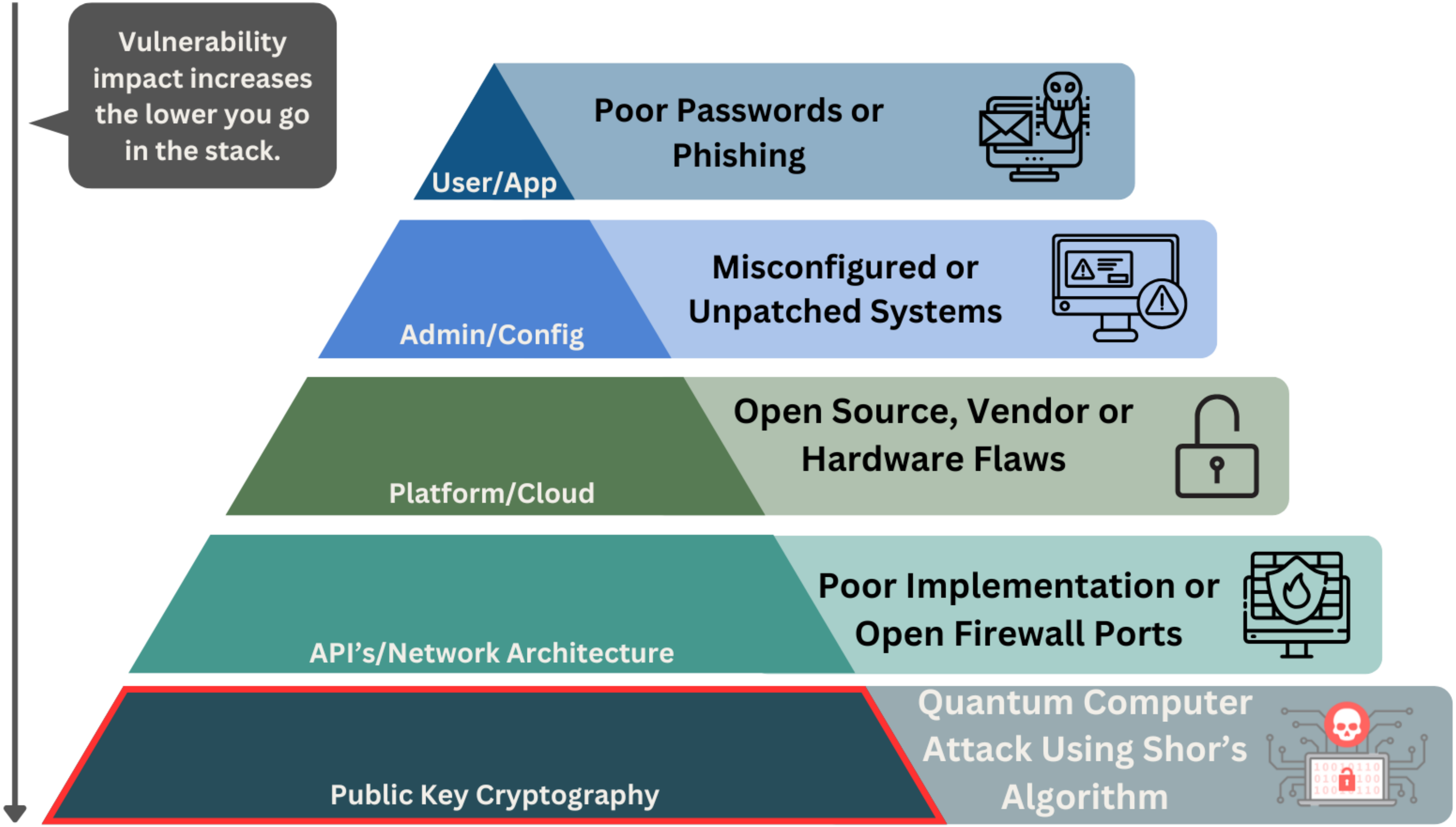
At the GTC 2025 in San Jose, California, March 20th 2025

*Nvidia CEO **Jensen Huang** admitted he was wrong about timeline for quantum, surprised his comments hurt stocks!*

(He said “15 years” was “on the early side” in considering how long it would be before the technology would be useful.)

http://observer.com
http://ionq.com

Potential Security Vulnerability Causes



Preparing for a „Quantum Crisis" I

Board of rising facts regarding new threats

Emerging Threats

– Quantum computers could break cryptographic algorithms like RSA and ECC, essential to current security. Preparing now can prevent future vulnerabilities.

Regulatory Compliance

– Financial institutions face strict data protection regulations. Adopting quantum-resistant measures ensures future compliance. The world's finance system still is to be rated 'fragile'.

Preparing for a ,,Quantum Crisis'' II

Board of rising facts regarding new threats

Customer Trust and Reputation

– Cutting-edge security boosts customer trust and protects reputation, offering a competitive edge.

Long-term Security

– Transitioning to PQC keeps data secure even if intercepted today and decrypted later by quantum computers. QKD provides a theoretically unbreakable communication method.

Preparing for a ,,Quantum Crisis'' III

Post-Quantum Cryptography (PQC)

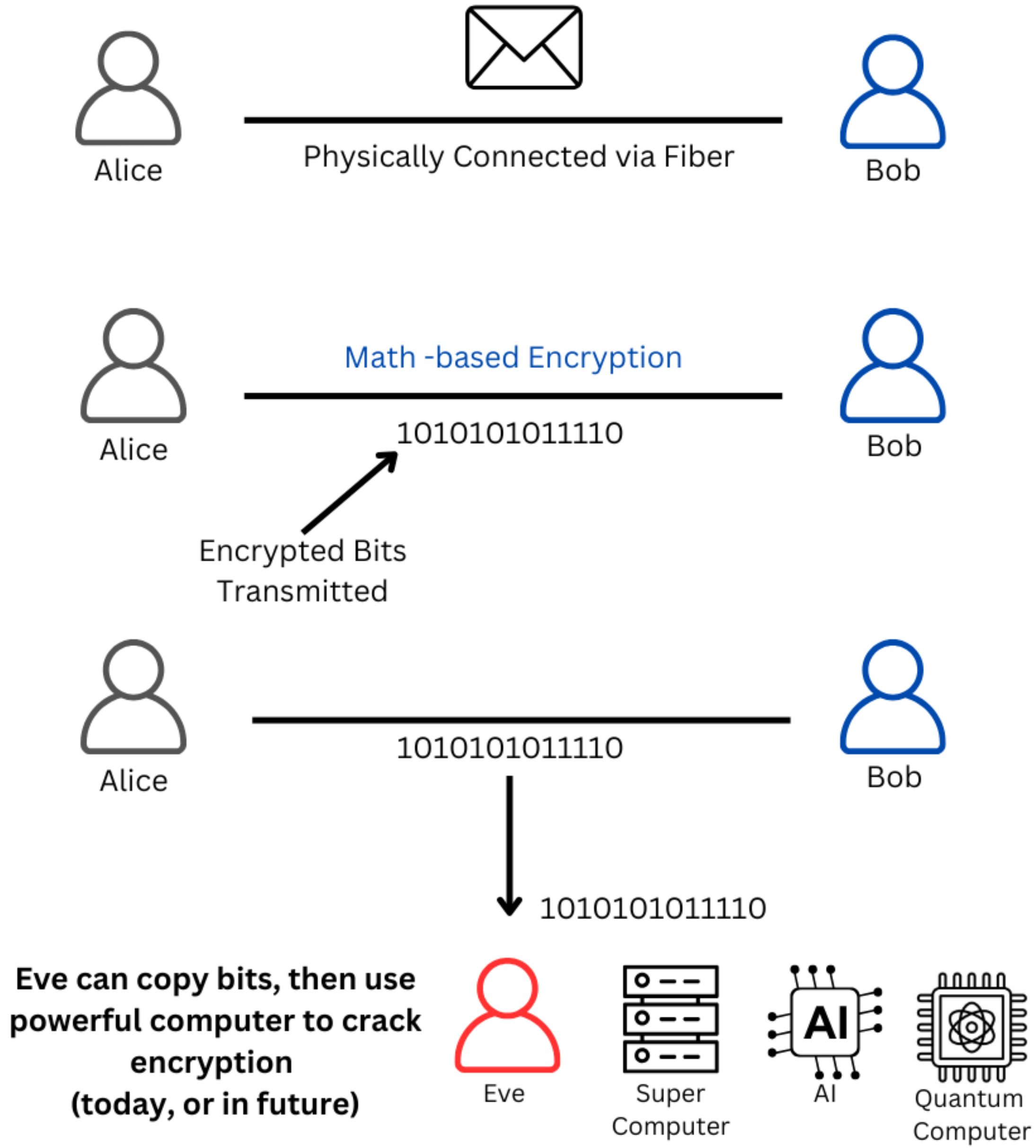
- Todays Asymmetrical encryption
- Algorithm based
- NIST standards (Aug '24)
- Already available and in daily use

Harvest now decrypt later

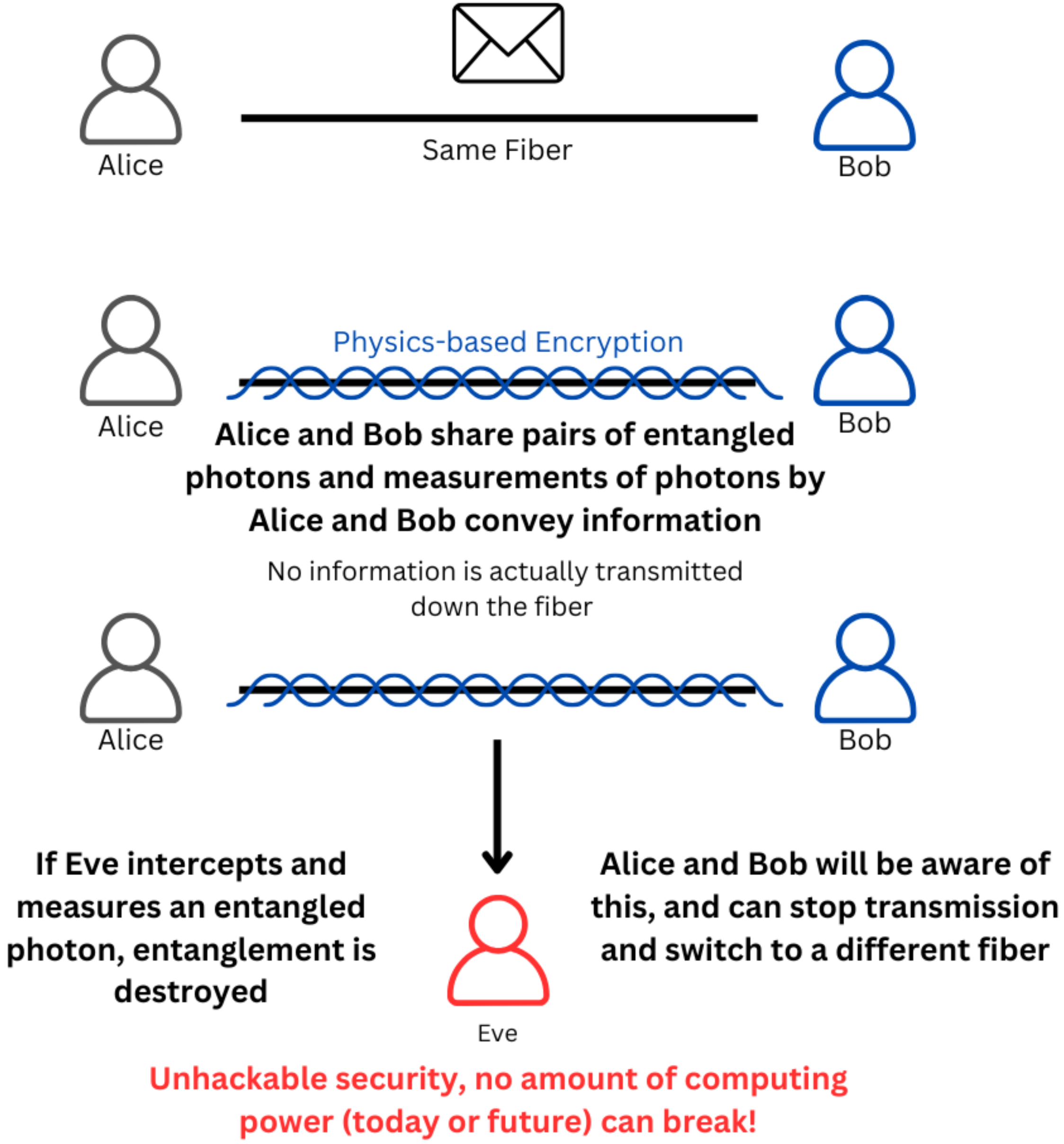
Quantum Key Distribution (QKD)

- Symmetrical encryption
- Hardware based
- Special purpose infrastructure needed
- Still under development

Classical Secure Communication



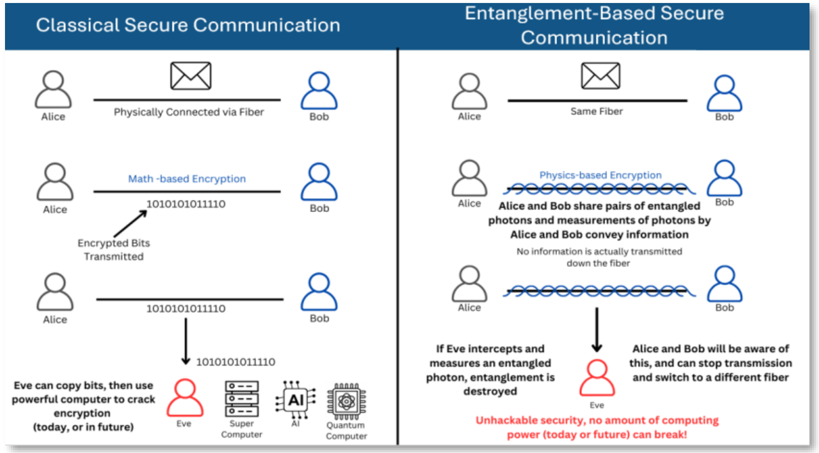
Entanglement-Based Secure Communication



Preparing for a „Quantum Crisis" IV

Authentication and Trust issues persists beyond established Quantum Security ⟶

- <u>Identity fraud</u>
- <u>Eavesdropping locally & side channel attacks</u>



- Progress in securing Metro IT networks e.g. is promising but just securing "A<··>B" isn't enough

Qunnect Sets New Benchmark in Quantum Networking on the GothamQ Network in New York City

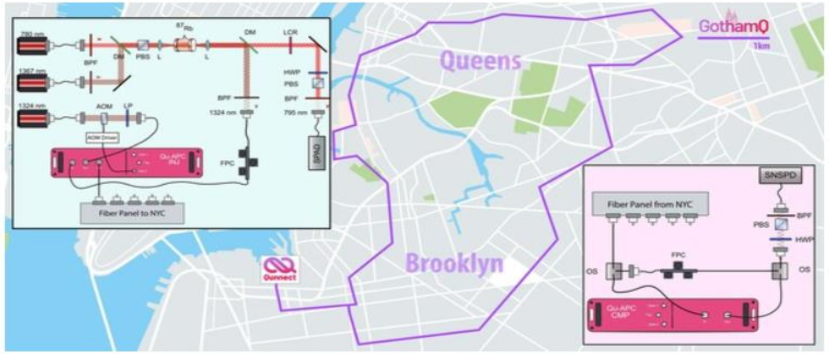


Diagram of the 54 Km GothamQ Quantum Networking Testbed in New York. Credit: Qunnect

Search...

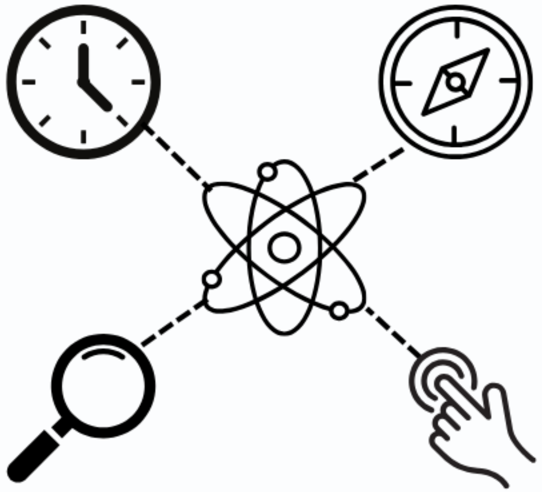
Recent Posts

- IonQ Announces Third Quarter Financial Results
- IonQ to Acquire the Assets of Qubitekk to Strengthen Its Position in Quantum Networking

https://www.qunnect.inc

QT Sensing

Quantum sensing



Key Principles:

- Superposition
- Entanglement
- Quantum Interference

Platforms used:

- NV centers in diamond
- Trapped ions
- Cold atoms
- Superconducting circuits
- Photon-based systems

Common applications:

- Magnetic field sensing
- Gravitational sensing
- Timekeeping
- Inertial navigation

Quantum Computing and AI

Quantum advantages in ai:

Exponential acceleration: quantum computers can significantly reduce the training time of AI models, especially for large data sets.

Advanced model capabilities: quantum AI can develop complex models that classical algorithms cannot solve efficiently.

Efficient optimization: Many AI tasks, such as neural network training and decision making, are optimization problems. Quantum algorithms such as the Grover algorithm offer significant advantages here.

Areas of application:

Optimization: Quantum AI can efficiently solve optimization problems in logistics, financial markets, and energy distribution.

Pattern recognition: Quantum AI is unbeatable when it comes to analyzing large and complex data sets, such as in medical diagnostics or image processing.

Machine learning: quantum algorithms can improve models of supervised, unsupervised and reinforcement learning, such as training quantum Boltzmann machines or quantum neurons.

Quantum Computing relies on huge coding inventions efforts I

Quantum & AI Software improvements required

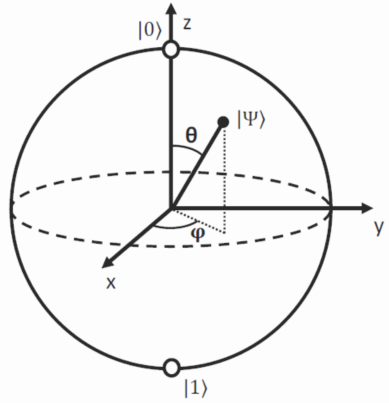
sample code

Qiskit

qrisp

```
from qiskit import (QuantumCircuit, QuantumRegister,
ClassicalRegister, Aer, execute)
from qiskit.circuit.library import RGQFTMultiplier
n = 6
a = QuantumRegister(n)
b = QuantumRegister(n)
res = QuantumRegister(2*n)
cl_res = ClassicalRegister(2*n)
qc = QuantumCircuit(a, b, res, cl_res)
for i in range(len(a)):
    if 3 & 1<<i: qc.x(a[i])
for i in range(len(b)):
    if 4 & 1<<i: qc.x(b[i])
qc.append(RGQFTMultiplier(n, 2*n),
list(a) + list(b) + list(res))
qc.measure(res, cl_res)
backend = Aer.get_backend('qasm_simulator')
counts_dic = execute(qc, backend).result().get_counts()
print({int(k, 2) : v for k, v in counts_dic.items()})
#Yields: {12: 1024}
```

```
from qrisp import Quant
n = 6
a = QuantumFloat(n)
b = QuantumFloat(n)
a[:] = 3
b[:] = 4
res = a*b
print(res)
#Yields: {12: 1.0}
```



qubits

quantum bit

Quantum Computing relies on huge coding inventions efforts II

Quantum Software research already adopted real problems

e.g. use-case

- Risk analysis
- Q-ML for QKD

  using patterns like:
  - Cloning machines
  - Parallel phase estimation
  - Quantum amplitude estimation (own IP)

'JQM'

- Quantum OS: use-case enabling, exercising algo's on **x-million Qubits**

arXiv:2103.05475v1 [quant-ph] 9 Mar 2021

A Quantum Algorithm for the Sensitivity Analysis of Business Risks

M.C. Braun*[1], T. Decker*[1], N. Hegemann*[1], S.F. Kerstan*[1], and C. Schäfer*[2]

[1]JoS QUANTUM GmbH, Frankfurt am Main, Germany
[2]Deutsche Börse Group, Frankfurt am Main, Germany

March 9, 2021

Abstract

We present a novel use case for quantum computation: the sensitivity analysis for a
used at Deutsche Börse Group. Such an analysis is computationally too expensive to
classical computers. We show in detail how the risk model and its analysis can be implem
quantum circuit. We test small scale versions of the model in simulation and find that th
quadratic speedup compared to the classical implementation used at Deutsche Börse Gr
realized. Full scale production usage would be possible with less than 200 error corrected
Our quantum algorithm introduces unitary but imperfect oracles which use Quantum
Estimation to detect and mark states. This construction should be of general interest and
theoretical results regarding the performance of Grover's search algorithm with imperfec

1 Introduction

Quantum computers promise to speed up some calculations which would require an i
amount of calculation time on classical computers. Readers looking for a technical intro
the subject will find reference [1] useful, although it does not cover the most recent de
that matter for this work, in particular reference [2].
The best known quantum algorithms either offer a super-polynomial speedup over know
implementations like Shor's algorithm [3] or a quadratic speedup like Grover's search [4, 5
will play an important role for our application. Many other quantum algorithms are
or extensions of the ideas of these algorithms and they exhibit the same speedups. An
example of an extension of Grover's algorithm is Quantum Amplitude Estimation ("QAE"
also plays an important role in the quantum implementation of our use case.
Despite the progress regarding algorithms and hardware, very few concrete business probl
can be solved with relevant speed gains on quantum computers, have been described in the

arXiv:2410.01904v2 [quant-ph] 27 Feb 2025

QKD as a Quantum Machine Learning task

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We propose considering Quantum Key Distribution (QKD) protocols as a use case for Quantum Machine Learning (QML) algorithms. We define and investigate the QML task of optimizing eavesdropping attacks on the quantum circuit implementation of the BB84 protocol. QKD protocols are well understood and solid security proofs exist enabling an easy evaluation of the QML model performance. The power of easy-to-implement QML techniques is shown by finding the explicit circuit for optimal individual attacks in a noise-free setting. For the noisy setting we find, to the best of our knowledge, a new cloning algorithm, which can outperform known cloning methods. Finally, we present a QML construction of a collective attack by using classical information from QKD post-processing within the QML algorithm.

I. INTRODUCTION

Quantum Machine Learning (QML) [1, 2] has attracted significant interest in recent years with the promise of improving our capabilities of learning from data using the computing potential of quantum systems. Because of the state of quantum hardware, it is currently not possible to run QML algorithms on noise-free large-scale systems. For this reason, quantum algorithms are mostly benchmarked using numerical simulations. This limits QML use cases to relatively small-scale models on reduced data sets and makes the comparison to classical models a challenging task. For a comprehensive analysis of the current challenges of benchmarking QML algorithms, we refer readers to [3].

In the light of this situation, we see Quantum Key Distribution (QKD) as an attractive field of research for QML: QKD protocols operate on small-scale quantum systems, and those systems are already sufficient for interesting QML applications, as we will show in this work.

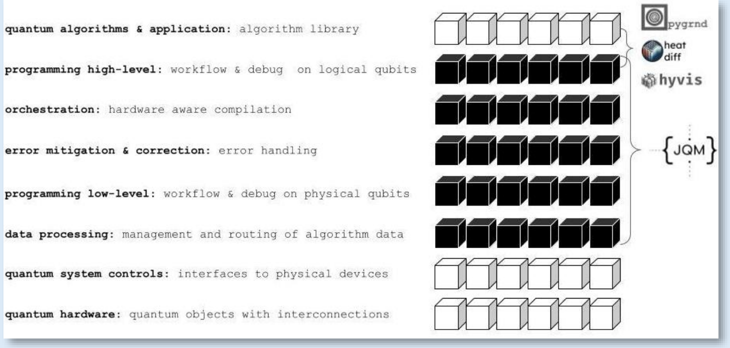
The literature on quantum key distribution (QKD) has grown from a few pioneering papers in the 1980s, such as [4], which established the idea of QKD with the introduction of the BB84 protocol, to an impressive number of new protocols, for example the prominent E91 [5] and six-state [6] protocols, security proofs for many protocols, e.g. [7] for BB84, and later also security proofs that deal with finite-size keys [8]. An important part of QKD is the classical post-processing, which consists of error

on them can be expressed through parametrized quantum circuits. With a proper choice of loss function, QCL can then be used to optimize such an attack.

We show that with a relatively shallow QCL ansatz and appropriate loss functions, we find the optimal individual attack on the BB84 protocol with a noise-free quantum channel, which is known to be the Phase Covariant Cloning Machine (PCCM) [14]. That this is possible was noticed earlier in [15]. We also show that in the presence of noise, a QCL attack can outperform the PCCM. This demonstrates that it is not the optimal individual attack in general. In the final example we apply QCL to construct a, within the expected accuracy, optimal[1] collective attack on BB84 when parity information about pairs of transmitted qubits is exchanged between Alice and Bob for post-processing the key.

We stress that our examples do not break any existing BB84 security proofs. From a QKD point of view, we provide a convenient construction of explicit representations of attacks on the protocol[2]. Some explicit constructions exist in the literature, such as in [14] and [16], but in the light of existing security proofs, the actual attacks appear to be of limited interest. However, from a QML point of view, our examples demonstrate the surprising power of relatively simple QCL constructions and thus a guideline for circuit design and evaluation.

II. BRIEF REVIEW OF THE BB84 PROTOCOL



JoS QUANTUM ALGORITHMS MADE IN GERMANY

However…

In summary, the integration of quantum computing into AI shows enormous potential for pushing the boundaries of conventional technologies.

However, this fusion also raises critical ethical questions.

Solving Unresolved Problems

- Climate research
- Medical technology
- Material science
- Artificial intelligence
- Quantum sensing
- Supply chain and logistics
- Defense & aerospace
- Fundamental physics

6 Out of the 17 SDGs Impacted by Quantum Advantages

SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WELL-BEING

– Quantum simulations for drug discovery (e.g., against malaria, cancer, rare diseases)
– Early detection of complex diseases through quantum-enhanced pattern recognition in medical data

4 QUALITY EDUCATION

– Democratized access to quantum computers via cloud platforms
– Global educational initiatives in quantum technology

7 AFFORDABLE AND CLEAN ENERGY

– Optimization of power grids via quantum algorithms (load balancing, efficiency)
– New sensor technologies for better batteries

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

– Quantum-based manufacturing simulations and for sustainable production processes
– Use in emergency logistics and infrastructure planning

11 SUSTAINABLE CITIES AND COMMUNITIES

– Optimization of urban infrastructures (transport, logistics, energy consumption)
– Use in disaster management and humanitarian logistics

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

– Highly secure communication via quantum encryption (e.g., for diplomacy, justice, elections)
– Protection of critical infrastructure through secure networks

The Diplomatic Council supports the Sustainable Development Goals

The Collingridge Dilemma in Regulating Quantum Technologies

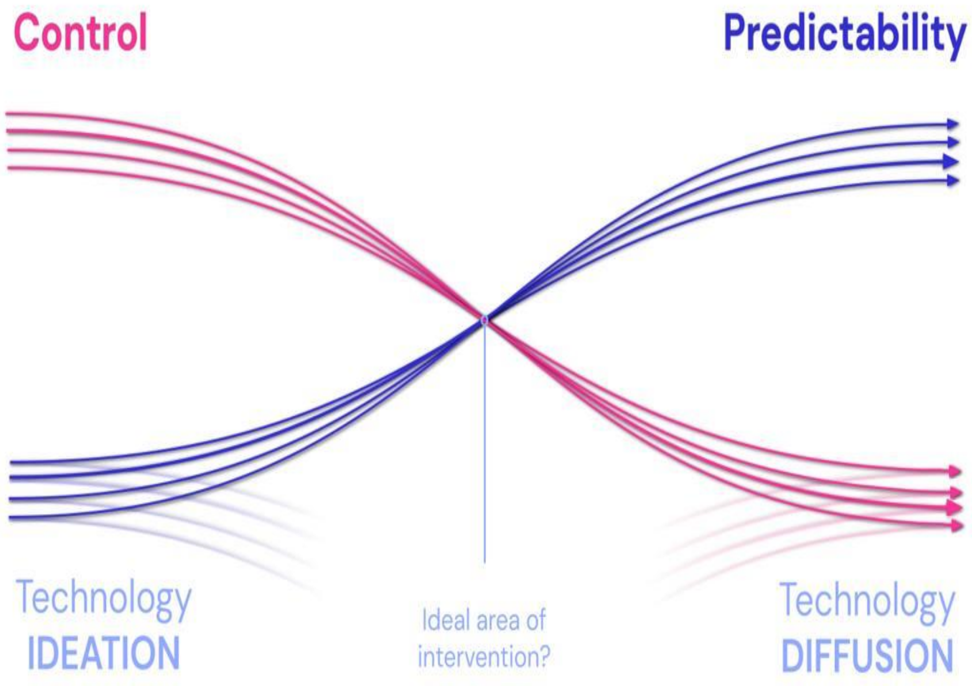
The Collingridge Dilemma states that early-stage regulation is difficult due to a lack of knowledge,
while late-stage regulation becomes challenging because the technology is already entrenched.

Relevance to Quantum Technologies:

- Uncertainty about long-term societal, economic, and ethical implications
- Potential future dominance of quantum computing and quantum cryptography

Solution Approaches:

- Proactive yet flexible regulatory frameworks
- Iterative ethics assessments aligned with technological progress



Adapted from Besti, F. & Samorè, F. (2018). Responsibility driven design for the future self-driving society. Fondazione Giannino Bassetti

Ethical Challenges in Quantum Technologies

Data Security:
Quantum computers could break current encryption standards, threatening cybersecurity

Geopolitical Risks:
Quantum supremacy could lead to technological dominance by a few countries, increasing global inequalities

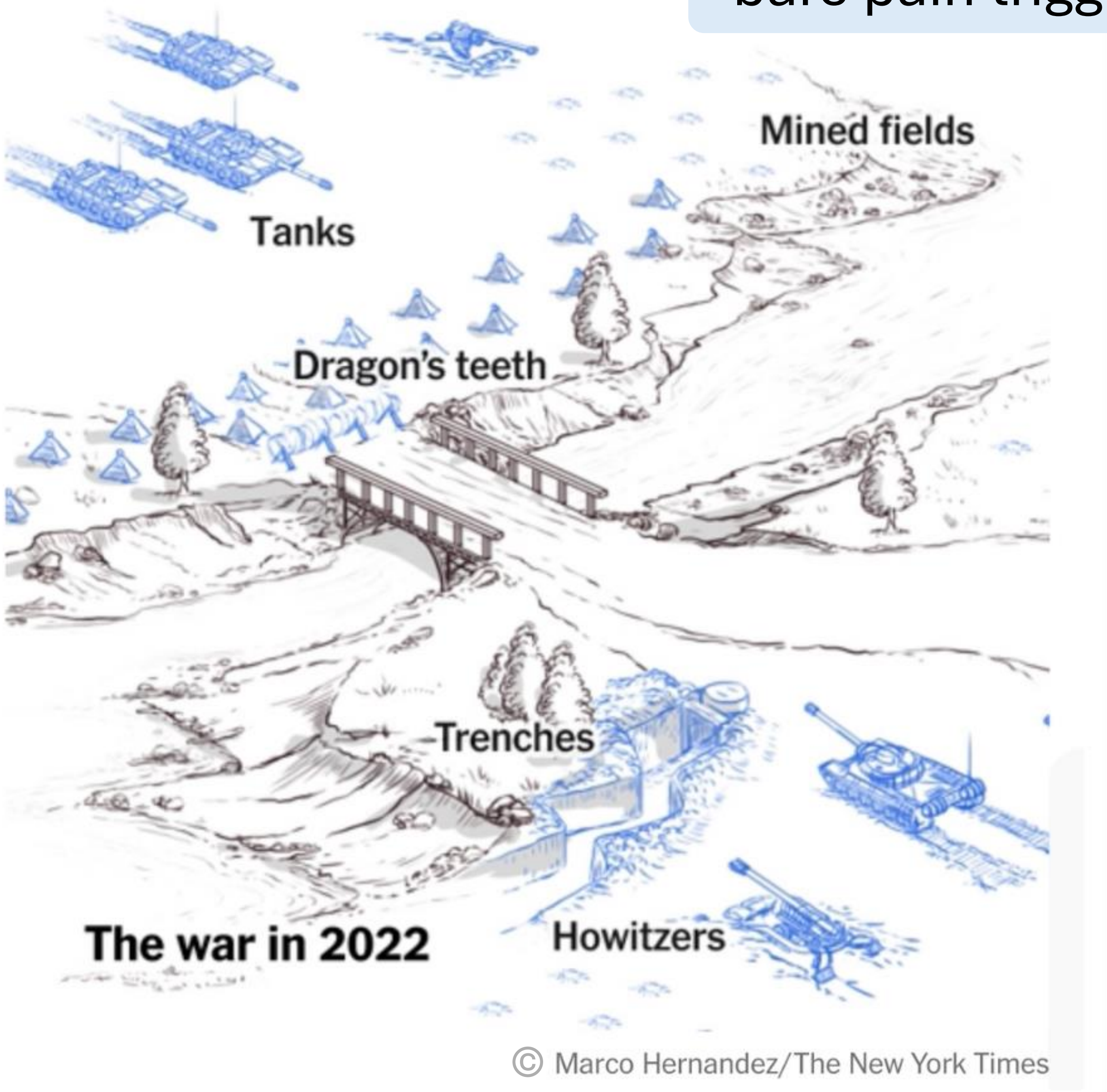
Economic Disruption:
Job displacement due to q-automation in various industries

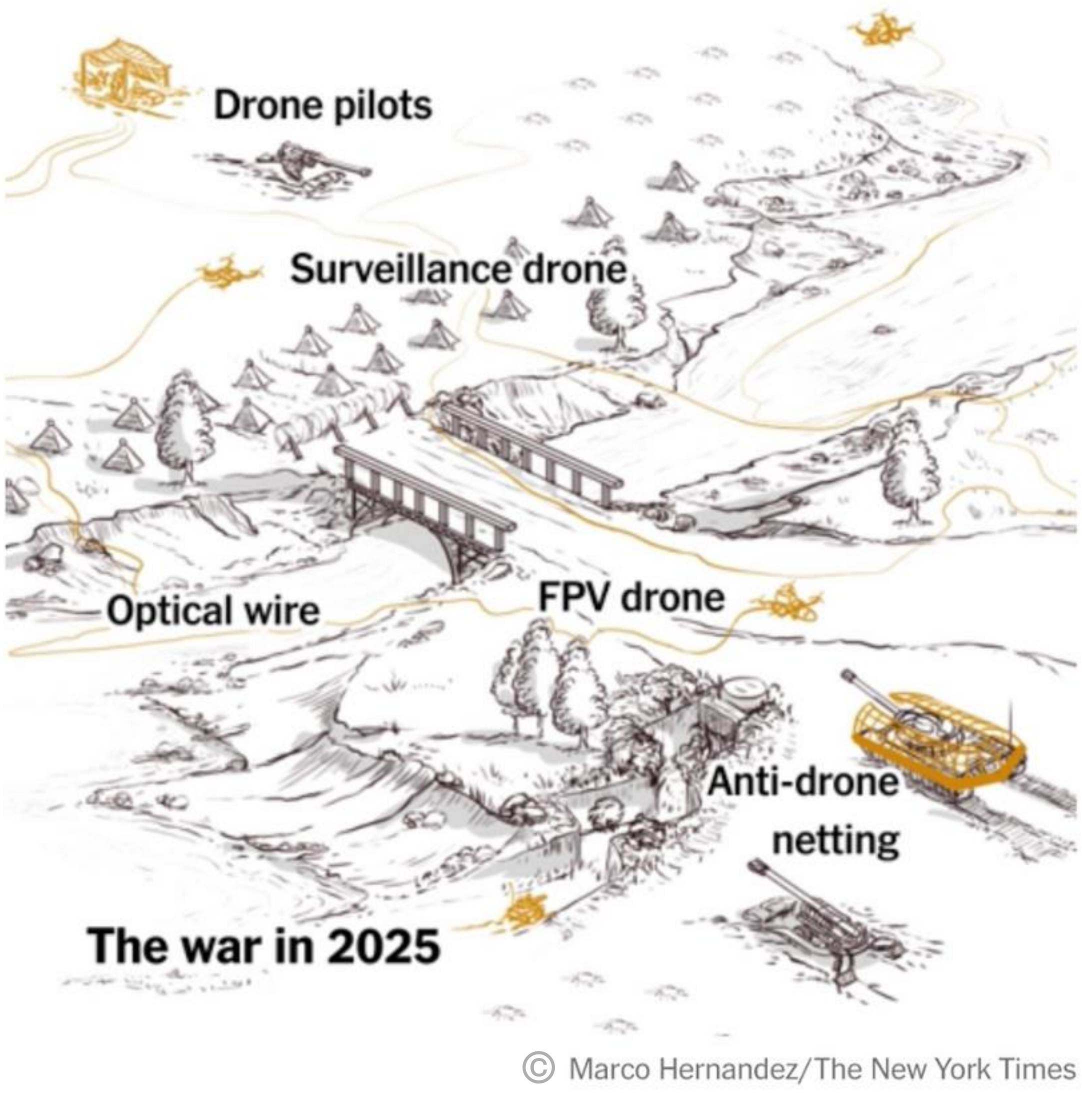
Unintended Consequences:
Unforeseen applications of quantum technologies that may pose risks to privacy and security

Access and Equity:
Risk of widening the technological divide between developed and developing nations

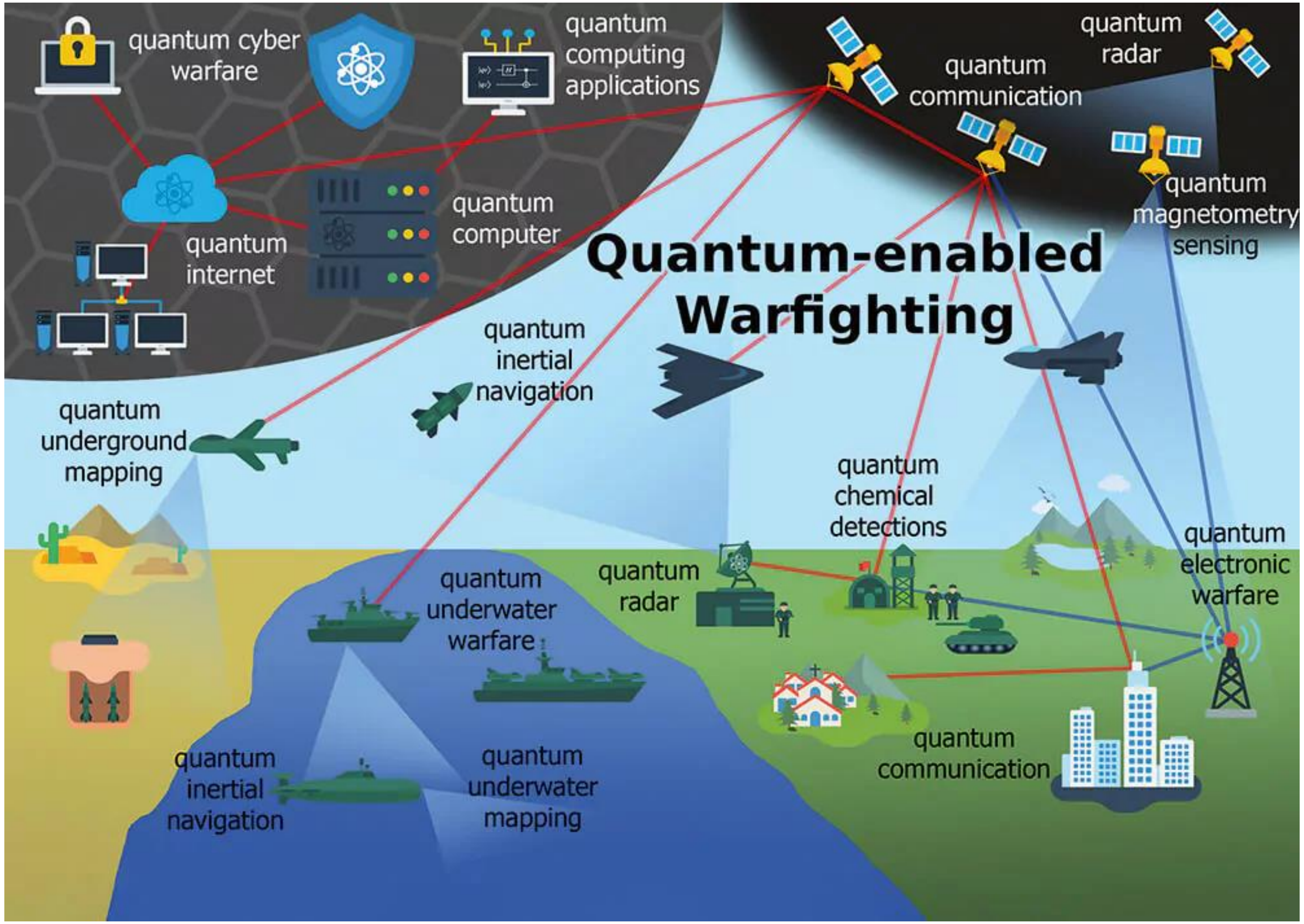
Ethical Challenges in Quantum Technologies

bare pain triggers disruptiveness





Ethical Challenges in Quantum Technologies



https://www.japcc.org/articles/quantum-technology-for-defence/

Ethical and Technology Impact Assessment of QT

Current Research on Technology Assessment in QT

United Nations Ethics Recommendations:

The UN emphasized the importance of ethical guidelines in emerging technologies, including quantum computing (UNESCO - Ethics of Science and Technology)

European Union Reports:

Emphasizes responsible innovation and ethical oversight (EU Science Hub - Quantum Ethics)

Institute for Technology Assessment and Systems Analysis (ITAS):

Interdisciplinary evaluation of quantum developments (https://www.itas.kit.edu/english/rg_light_coen24_taqt.php)

Key Recommendations:

- Early-stage ethical and social impact assessments
- Establishing ethical committees in quantum research

Lessons from Other Technologies

Learning from Past Technology Assessments

Genetic Engineering:

- Ethical concerns over genetic modification and biosecurity risks
- Public debates led to regulatory frameworks like CRISPR guidelines

Nuclear Technology:

- Initial optimism turned to concern over safety and proliferation risks
- Global treaties emerged to control nuclear applications

Quantum Technology Takeaways:

- Ethical foresight prevents future societal crises
- Transparency and public engagement are key

Ethical Roadmap for Quantum Technologies

Strategies for Responsible Quantum Technology Development

Multidisciplinary Collaboration:
- Involving ethicists, policymakers, and scientists

- **Adaptive Regulatory Frameworks:**
  - Policies that evolve with technological advancements

- **Public Awareness & Transparency:**
  - Open discourse on the ethical use of quantum technologies

- **International Cooperation:**
  - Global guidelines for equitable quantum development

Source Picture: E-badge-nadsp

Conclusions I

Pro

Computing Power

- Quantum computers can potentially solve problems infeasible for classical computers (e.g., cryptography, optimization, drug discovery).
- Expected impact on **materials science**, **logistics**, **climate modeling**, and **AI**.

Secure Communication

- Quantum Key Distribution (QKD) offers **unbreakable encryption**, enhancing cybersecurity.
- Potential role in **data sovereignty** and **national security**.

Sensing and Metrology

- Quantum sensors promise extreme precision in **medical imaging**, **navigation**, **earth observation**, and **gravitational detection**.
- May revolutionize **healthcare**, **autonomous systems**, and **climate monitoring**.

Economic Competitiveness

- Strategic importance for nations and companies to stay ahead in the **quantum race**.
- High potential for **new markets**, **startups**, and **job creation**.

Scientific Advancements

- Deeper understanding of quantum mechanics leading to **new physics** and **technological revolutions**.

Contra

Cryptography Disruption

- Quantum computers could break today's encryption methods (RSA, ECC), leading to data breaches.
- Urgent need for **post-quantum cryptography**.

Ethical and Geopolitical Issues

- Risks of **militarization**, **surveillance**, and **inequality**.
- May exacerbate **digital divides** between countries.

High Uncertainty

- Timeline for practical quantum advantage is uncertain.
- Significant **technical hurdles** and **scalability** issues remain.

Workforce and Education

- Lack of trained personnel.
- Need for **interdisciplinary education** and **diverse talent pipelines**.

Energy and Environmental Costs

- Quantum hardware (e.g., cryogenic systems) can be energy-intensive.
- Lifecycle assessments still underexplored.

Conclusions II

Thesis

For the development of humanity Quantum technology is able to create a significant and outstanding impact.

Nuclear power uncontrolled is inhuman.

- Deeper understanding of quantum mechanics leading to **new physics** and **technological revolutions**. An advantage for humanity.
- Analogy: Poisonous for human beings **some natural plants bearing fatal threats to our life and health.** Others heal.

Recommendation

- Nuclear **power**
- Quantum **technology**

Conclusions II

Thesis

For the development of humanity Quantum technology is able to create a significant and outstanding impact.

consistently controlled ..

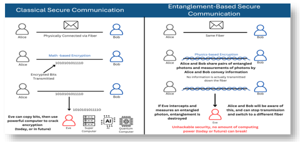
Nuclear power ~~uncontrolled is inhuman.~~

.. is human.

– Deeper understanding of quantum mechanics leading to **new physics** and **technological revolutions**. An advantage for humanity.

– Analogy: Poisonous for human beings **some natural plants bearing fatal threats to our life and health.** Others heal.

– <u>Evaluate at least Quantum secure communication!</u> ⟶



Recommendation

“Quantum twist“

– Nuclear **technology**

<u>covered by</u>

– Quantum **power**

Call to Action

- Prepare for the Quantum crisis
- Monitor the 3rd Quantum revolution
- Contribute to the Quantum advantages
- Join the ‘Quantum twist’

100 Years Quantum Mechanics
Werner Heisenberg 1925
Uncertainty Principle